AR TARGET SHEET

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cross-sections) of the solute BTCs were generated for the three solute species and are shown in Attachment E3, Figures E3.103 through E3.105 for technetium-99, chromium, and nitrate, respectively. These results indicate that locating the inventory near the water table greatly influences solute transport to the first compliance point, yielding earlier peak arrival times and higher peak concentrations. For cross-section S-CC', compared with the uniform distribution (Case 1), peak concentrations at the first compliance point, due to the displaced-nonuniform distribution, were 23.6 to 41.7 times higher, depending on the solute. The corresponding factors varied from 4.61 to 9.40 for cross-section SX-DD' and 12.9 to 25.4 for cross-section SX-FF', depending on the solute.

Table E.21. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 7

Parameter	S-CC'	SX-DD'	SX-FF'
Tc-99			
Arrival Time	2006.9 yr	2014.9 yr	2007.6 yr
Peak Conc.	5.754×10^{6} pCi/L	1.159×10^{7} pCi/L	7.285×10^{6} pCi/L
Max. Initial Conc.*	6.262×10^{8} pCi/L	2.033×10^{9} pCi/L	4.425×10^{8} pCi/L
Cr			
Arrival Time	2014.6 yr	2019.6 yr	2014.3 yr
Peak Conc.	6.640×10^{4} µg/L	7.633×10^{5} µg/L	6.372×10^{4} µg/L
Max. Initial Conc.	1.710×10^{7} µg/L	1.074×10^{8} µg/L	7.290×10^{6} µg/L
NO_3			
Arrival Time	2006.6 yr	2014.9 yr	2005.9 yr
Peak Conc.	2.447×10^{7} µg/L	1.545×10^{7} µg/L	1.310×10^{7} µg/L
Max. Initial Conc.	2.711×10^{9} µg/L	2.159×10^{9} µg/L	7.048×10^{8} µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

E.4.8 DENSITY AND VISCOSITY EFFECTS CASE (CASE 8)

The density and viscosity effects suite of simulations, Case 8, investigated solute transport through three cross-sections in the S and SX tank farms considering natural surface infiltration, with no water-line leaks and closure barrier by the year 2040. This suite of simulations differs from the Case 1 simulations in that the aqueous phase density and viscosity were dependent on the nitrate concentration, as described in Section E.2.2.5. These simulations were initialized using a steady-flow solution defined by the surface recharge rate of 100 mm/yr and a hydraulic gradient in the unconfined aquifer. Inventories of the four contaminant species were initialized using the uniform distribution pattern. Plot-file output for these simulations was generated at the years 2000, 2010, 2040, 2540, and 3000 and include values for the aqueous saturation, aqueous pressure, aqueous moisture content, and concentrations for the four solute species.

Solute BTCs at the first compliance point for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Attachment E3, Figures E3.106 through E3.114 for the three solute species (technetium-99, chromium, and nitrate), respectively. Aqueous flux at the water table for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Figures E3.115 through E3.117, respectively. Times and aqueous concentrations for the BTC peaks at the first compliance boundary are shown in Table E.22. Area-weighted averages (across the three cross-sections) of the solute BTCs were generated for the three solute species and are shown in Attachment E3, Figures E3.118 through E3.120 for technetium-99, chromium, and nitrate, respectively.

Table E.22. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 8

Parameter	S-CC'	SX-DD'	SX-FF'
Tc-99			
Arrival Time	2032.7 yr	2050.0 yr	2032.3 yr
Peak Conc.	1.393×10^5 pCi/L	1.260×10^6 pCi/L	2.905×10^5 pCi/L
Max. Initial Conc.*	4.491×10^6 pCi/L	9.480×10^7 pCi/L	5.074×10^6 pCi/L
Cr			
Arrival Time	2050.3 yr	2052.3 yr	2051.3 yr
Peak Conc.	2.819×10^3 µg/L	1.052×10^5 µg/L	4.545×10^3 µg/L
Max. Initial Conc.	6.456×10^4 µg/L	1.244×10^7 µg/L	1.089×10^5 µg/L
NO_3			
Arrival Time	2032.7 yr	2050.0 yr	2032.3 yr
Peak Conc.	8.538×10^5 µg/L	3.423×10^6 µg/L	1.024×10^6 µg/L
Max. Initial Conc.	3.254×10^7 µg/L	4.448×10^8 µg/L	3.616×10^7 µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

Increasing nitrate concentration increases both the aqueous density and viscosity. These property changes have opposite effect; that is, increasing aqueous density increases the gravitational body force on a nitrate plume, but increasing viscosity reduces the plume fluidity. Because of the opposing flow effects, the solute migration toward the WMA S-SX boundary was nearly unchanged from the Case 1 simulations.

E.4.9 BASE CASE WITH 50 MM/YR METEORIC RECHARGE CASE (CASE 9)

The base case with 50 mm/yr meteoric recharge suite of simulations, Case 9, investigated solute transport through three cross-sections in WMA S-SX considering natural surface infiltration, with no water-line leaks and no interim surface barriers, but with a closure barrier by the year 2040. These simulations along with those from Cases 1, 10, and 11 form a sensitivity study on the effect of meteoric recharge on the migration of solutes to the WMA S-SX boundary.

The simulations in this case were initialized using a steady-flow solution defined by the surface recharge rate of 50 mm/yr and a hydraulic gradient in the unconfined aquifer. Inventories of the four contaminant species were initialized using the uniform distribution pattern. Plot-file output for these simulations was generated at the years 2000, 2040, 2540, and 3000 and include values for the aqueous saturation, aqueous pressure, aqueous moisture content, and concentrations for the four solute species. The moisture field for these simulations remains unchanged from the initial steady-flow field until the year 2040, when the closure barrier becomes effective.

Solute BTCs at the first compliance point for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Attachment E3, Figures E3.121 through E3.129, for the three solute species (technetium-99, chromium, and nitrate), respectively. Aqueous fluxes at the water table for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Figures E3.130 through E3.132, respectively. Breakthrough times and aqueous concentrations at the first compliance point are shown in Table E.23, along with the maximum initial aqueous concentrations. Area-weighted averages (across the three cross-sections) of the solute BTCs were generated for the three solute species and are shown in Attachment E3, Figures E3.133 through E3.135 for technetium-99, chromium, and nitrate, respectively.

Table E.23. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 9

Parameter	S-CC'	SX-DD'	SX-FF'
Tc-99			
Arrival Time	2055.9 yr	2074.0 yr	2054.3 yr
Peak Conc.	9.234×10^4 pCi/L	3.744×10^5 pCi/L	1.988×10^5 pCi/L
Max. Initial Conc.*	4.491×10^6 pCi/L	9.480×10^7 pCi/L	5.074×10^6 pCi/L
Cr			
Arrival Time	2072.3 yr	2081.7 yr	2070.3 yr
Peak Conc.	8.966×10^2 µg/L	2.221×10^4 µg/L	1.651×10^3 µg/L
Max. Initial Conc.	6.456×10^4 µg/L	1.244×10^7 µg/L	1.089×10^5 µg/L
NO_3			
Arrival Time	2055.3 yr	2071.3 yr	2054.0 yr
Peak Conc.	5.688×10^5 µg/L	1.048×10^6 µg/L	7.135×10^5 µg/L
Max. Initial Conc.	3.254×10^7 µg/L	4.448×10^8 µg/L	3.616×10^7 µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

The steady-flow saturation field for cross-section SX-DD' (tanks SX-107, SX-108, and SX-109) with 50 mm/yr of meteoric recharge is shown in Figure E.20. This field shows little variation from that for the 100 mm/yr meteoric recharge case (Case 1) (Figure E.8). Although this series of simulations yielded only slight changes in the initial mean saturation (Tables E.15 and E.24), peak concentrations and their arrival times at the WMA S-SX boundary changed considerably.

Reductions in solute concentrations at the WMA S-SX boundary were primarily correlated with the initial inventory distributions. The technetium-99 and nitrate solute concentrations were reduced to approximately 60% of the Case 1 values; whereas, the chromium solute concentrations showed reductions to approximately 30%. Comparisons of solute BTCs for the various initial meteoric recharge rates at the first compliance point are shown for each combination of cross-section and solute in Attachment E5, Figures E5.1 through E5.9. Comparisons of aqueous fluxes at the water table for the various initial meteoric recharge rates for the three cross-sections are shown in Figures E5.10 through E5.12.

Figure E.20. Case 9 Aqueous-Phase Saturation at 2000 (50 mm/yr) for Cross-Section SX-DD'

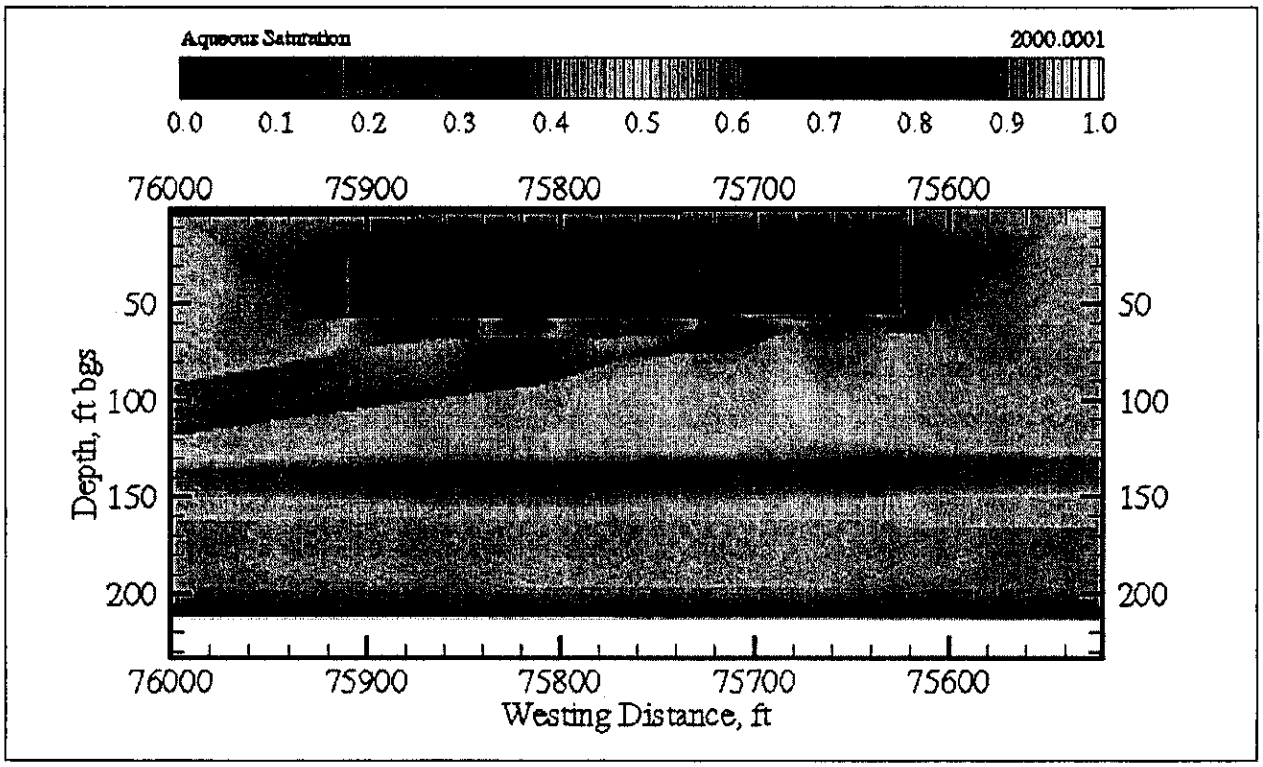


Table E.24. Case 9 Mean Aqueous-Phase Saturation

Year	Meteoric Recharge	S-CC'	SX-DD'	SX-FF'
2000	50 mm/yr	0.5135	0.5125	0.5057
2040	50 to 0.1 mm/yr	0.5135	0.5125	0.5057
2540	0.1 to 3.5 mm/yr	0.3625	0.3623	0.3576
3000	3.5 mm/yr	0.4115	0.4106	0.4060

The water table level showed little variation with the rate of surface recharge; therefore, the mean aqueous saturation in the cross-section gives a general indication of the effect of surface recharge on the flow environment. Mean aqueous phase saturations at selected times during the simulation period are shown in Table E.24 for the three cross-sections (S-CC', SX-DD', and SX-FF'). As expected, the mean saturations follow the trends in surface recharge (i.e., higher mean saturations at higher surface recharge). However, the rate of change in mean saturation is slow, as evidenced by the gradual decrease in saturation during transition from 50 to 0.1 mm/yr in 2040 until the next rate change in 2540. In contrast, the aqueous flow field changes almost immediately to variations in the surface recharge. The saturation values in Table E.24 show little variation between cross-sections.

E.4.10 BASE CASE WITH 30 MM/YR METEORIC RECHARGE (CASE 10)

The base case with 30 mm/yr meteoric recharge suite of simulations, Case 10, investigated solute transport through three cross-sections in WMA S-SX considering natural surface infiltration, with no water-line leaks and no interim surface barriers, but with a closure barrier by the year 2040. These simulations along with those from Cases 1, 9, and 11 form a sensitivity study on the effect of meteoric recharge on the migration of solutes to the WMA S-SX boundary.
The simulations in this case were initialized using a steady-flow solution defined by the surface recharge rate of 30 mm/yr and a hydraulic gradient in the unconfined aquifer. Inventories of the four contaminant species were initialized using the uniform distribution pattern. Plot-file output for these simulations was generated at the years 2000, 2040, 2540, and 3000 and include values for the aqueous saturation, aqueous pressure, aqueous moisture content, and concentrations for the four solute species. The moisture content field for these simulations remains unchanged from the initial steady-flow field until the year 2040, when the closure barrier becomes effective.

Solute BTCs at the first compliance point for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Attachment E3, Figures E3.136 through E3.144, for the three solute species (technetium-99, chromium, and nitrate), respectively. Aqueous fluxes at the water table for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Figures E3.145 through E3.147, respectively. Breakthrough times and aqueous concentrations at the first compliance point are shown in Table E.25, along with the maximum initial aqueous concentrations. Area-weighted averages (across the three cross-sections) of the solute BTCs were generated for the three solute species and are shown in Attachment E3, Figures E3.148 through E3.150 for technetium-99, chromium, and nitrate, respectively.

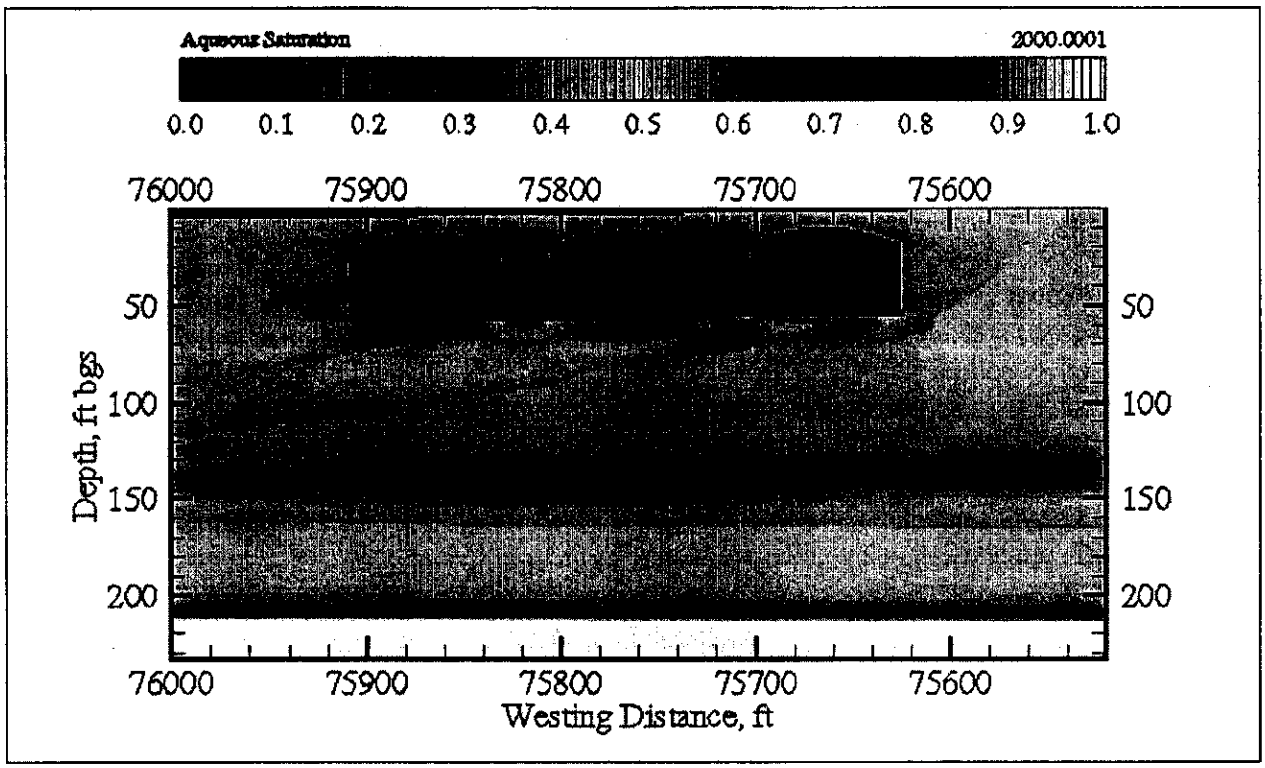
Table E.25. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 10

Parameter	S-CC'	SX-DD'	SX-FF'
Tc-99			
Arrival Time	2073.0 yr	2125.3 yr	2070.3 yr
Peak Conc.	5.219×10^4 pCi/L	1.114×10^5 pCi/L	1.233×10^5 pCi/L
Max. Initial Conc.*	4.491×10^6 pCi/L	9.480×10^7 pCi/L	5.074×10^6 pCi/L
Cr			
Arrival Time	2115.3 yr	3000.0 yr	2070.3 yr
Peak Conc.	3.013×10^2 µg/L	7.248×10^3 µg/L	5.903×10^2 µg/L
Max. Initial Conc.	6.456×10^4 µg/L	1.244×10^7 µg/L	1.089×10^5 µg/L
NO_3			
Arrival Time	2072.3 yr	2113.0 yr	2070.0 yr
Peak Conc.	3.268×10^5 µg/L	3.240×10^5 µg/L	4.324×10^5 µg/L
Max. Initial Conc.	3.254×10^7 µg/L	4.448×10^8 µg/L	3.616×10^7 µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

The steady-flow saturation field for cross-section SX-DD' (tanks SX-107, SX-108, and SX-109) with 30 mm/yr of meteoric recharge is shown in Figure E.21. The saturation field shows slight variation from those for the 50 mm/yr (Case 9) and 100 mm/yr (Case 1) meteoric recharge cases (Figures E.8 and E.20). Most notable is the overall reduction in saturation and the reduction in shadowing beneath the tanks. The effects of lowering the initial meteoric recharge to 30 mm/yr were similar to those of lowering the recharge from 100 to 50 mm/yr; peak concentrations at the WMA S-SX boundary were lowered and arrival times of the concentration peaks were delayed. Again, reductions in solute concentrations at the WMA S-SX boundary were primarily correlated with the initial inventory distributions. Comparisons of solute BTCs for the four initial meteoric recharge rates (100, 50, 30, and 10 mm/yr) at the first compliance point are shown for each combination of cross-section and solute in Attachment E5, Figures E5.1 through E5.9. Likewise, comparisons of aqueous fluxes at the water table for the four initial meteoric recharge rates for the three cross-sections are shown in Figures E5.10 through E5.12.

Figure E.21. Case 10 Aqueous-Phase Saturation at 2000 (30 mm/yr) for Cross-Section SX-DD'



The water table level showed little variation with the rate of surface recharge; therefore, the mean aqueous saturation in the cross-section gives a general indication of the effect of surface recharge on the hydrologic environment. Mean aqueous phase saturations at selected times during the simulation period are shown in Table E.26 for the three cross-sections (S-CC', SX-DD', and SX-FF'). The saturation values in Table E.26 show little variation between cross-sections.

Table E.26. Case 10 Mean Aqueous-Phase Saturation

Year	Meteoric Recharge	S-CC'	SX-DD'	SX-FF'
2000	30 mm/yr	0.4902	0.4893	0.4829
2040	30 to 0.1 mm/yr	0.4902	0.4893	0.4829
2540	0.1 to 3.5 mm/yr	0.3625	0.3623	0.3576
3000	3.5 mm/yr	0.4115	0.4106	0.4060

E.4.11 BASE CASE WITH 10 MM/YR METEORIC RECHARGE (CASE 11)

The base case with 10 mm/yr meteoric recharge suite of simulations, Case 11, investigated solute transport through three cross-sections in the WMA S-SX considering natural surface infiltration, with no water-line leaks and no interim surface barriers, but with a closure barrier by the year 2040. These simulations along with those from Cases 1, 9, and 10 form a sensitivity study on the

effect of meteoric recharge on the migration of solutes to the WMA S-SX boundary. The simulations in this case were initialized using a steady-flow solution defined by the surface recharge rate of 10 mm/yr and a hydraulic gradient in the unconfined aquifer. Inventories of the four contaminant species were initialized using the uniform distribution pattern. Plot-file output for these simulations was generated at the years 2000, 2040, 2540, and 3000 and include values for the aqueous saturation, aqueous pressure, aqueous moisture content, and concentrations for the four solute species. The moisture content field for these simulations remains unchanged from the initial steady-flow field until the year 2040, when the closure barrier becomes effective.

Solute BTCs at the first compliance point for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Attachment E3, Figures E3.151 through E3.159, for the three solute species (technetium-99, chromium, and nitrate), respectively. Aqueous fluxes at the water table for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Figures E3.160 through E3.162, respectively. Breakthrough times and aqueous concentrations at the first compliance point are shown in Table E.27, along with the maximum initial aqueous concentrations. Area-weighted averages (across the three cross-sections) of the solute BTCs were generated for the three solute species and are shown in Attachment E3, Figures E3.163 through E3.165 for technetium-99, chromium, and nitrate, respectively.

Table E.27. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 11

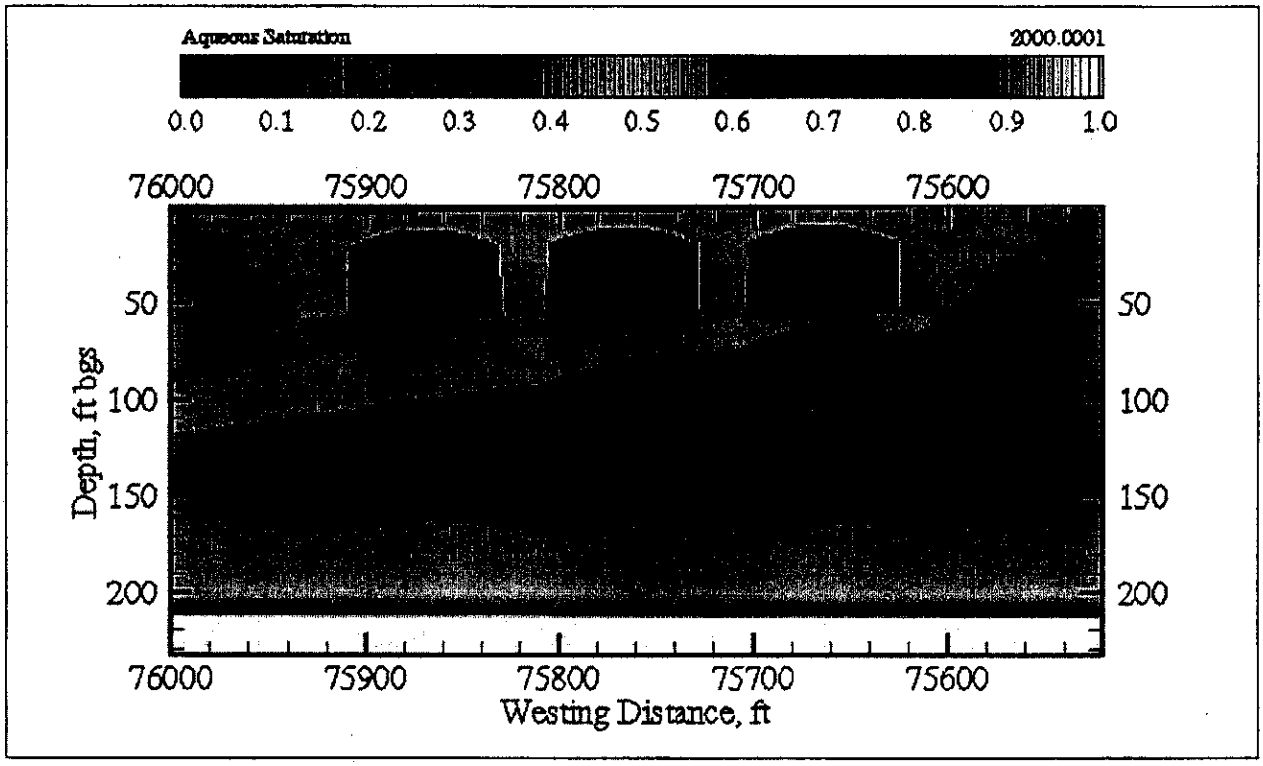
Parameter	S-CC'	SX-DD'	SX-FF'
Tc-99			
Arrival Time	2176.0 yr	3000.0 yr	2153.0 yr
Peak Conc.	1.057×10^4 pCi/L	6.775×10^4 pCi/L	2.783×10^4 pCi/L
Max. Initial Conc.*	4.491×10^6 pCi/L	9.480×10^7 pCi/L	5.074×10^6 pCi/L
Cr			
Arrival Time	3000.0 yr	3000.0 yr	3000.0 yr
Peak Conc.	1.609×10^2 µg/L	4.157×10^3 µg/L	3.133×10^2 µg/L
Max. Initial Conc.	6.456×10^4 µg/L	1.244×10^7 µg/L	1.089×10^5 µg/L
NO_3			
Arrival Time	2171.0 yr	3000.0 yr	2152.0 yr
Peak Conc.	6.819×10^4 µg/L	1.812×10^5 µg/L	9.895×10^4 µg/L
Max. Initial Conc.	3.254×10^7 µg/L	4.448×10^8 µg/L	3.616×10^7 µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

The steady-flow saturation field for cross-section SX-DD' (tanks SX-107, SX-108, and SX-109) with 10 mm/yr of meteoric recharge is shown in Figure E.22. Compared against the steady-flow saturation fields for 100, 50, and 30 mm/yr (Figures E.8, E.20, and E.21), the saturation field at 10 mm/yr shows no shadowing from the tanks and only slight increases in moisture between the

tanks. The 10 mm/yr recharge rate differs from the higher recharge rates investigated; the downward aqueous flow was sufficiently low to delay the peak arrival times to after the year 3000 for those solutes with shallower initial inventories. This behavior was predicted for chromium in all three cross-sections, and for technetium-99 and nitrate in cross-section SX-DD'. In general, the solute transport response to lower meteoric recharge is similar to that for surface barriers, but with greater consequence because of the earlier implementation of the reduced migration rates toward the groundwater. Comparisons of solute BTCs for the four initial meteoric recharge rates (100, 50, 30, and 10 mm/yr) at the first compliance point are shown for each combination of cross-section and solute in Attachment E5, Figures E5.1 through E5.9. Comparison of aqueous fluxes at the water table for the four initial meteoric recharge rates for the three cross-sections are shown in Figures E5.10 through E5.12.

Figure E.22. Case 11 Aqueous-Phase Saturation at 2000 (50 mm/yr) for Cross-Section SX-DD'



The water table level showed little variation with the rate of surface recharge; therefore, the mean aqueous saturation in the cross-section gives a general indication of the effect of surface recharge on the hydrologic environment. Mean aqueous phase saturations at selected times during the simulation period are shown in Table E.28 for the three cross-sections (S-CC', SX-DD', and SX-FF'). As expected the mean saturations follow the trends in surface recharge (i.e., higher mean saturations at higher surface recharge). The saturation values in Table E.28 show little variation between cross-sections.

Table E.28. Case 11 Mean Aqueous-Phase Saturation

Year	Meteoric Recharge	S-CC'	SX-DD'	SX-FF'
2000	50 mm/yr	0.4463	0.4455	0.4108
2040	50 to 0.1 mm/yr	0.4463	0.4455	0.4108
2540	0.1 to 3.5 mm/yr	0.3625	0.3623	0.3576
3000	3.5 mm/yr	0.4115	0.4106	0.4060

E.4.12 ALTERNATE INVENTORY DISTRIBUTION CASE (CASE 12)

The alternate inventory distribution suite of simulations, Case 12, investigated solute transport through three cross-sections in WMA S-SX considering natural surface infiltration, with no water-line leaks and closure barrier by the year 2040, and an alternate nonuniform distribution. The alternate inventory distributions are shown in Attachment E2, Figures E2.37 through E2.48. This suite of simulations differs from the Case 1 simulations in that an alternate distribution was used for the initial inventory; where the inventory distribution by depth was maintained but uniformly spread over the region beneath the tanks. These simulations were initialized using a steady-flow solution defined by the surface recharge rate of 100 mm/yr and a hydraulic gradient in the unconfined aquifer. Plot-file output for these simulations was generated at the years 2000, 2010, 2040, 2540, and 3000 and include values for the aqueous saturation, aqueous pressure, aqueous moisture content, and concentrations for the four solute species. The moisture content field for these simulations remains unchanged from the initial steady-flow field until the year 2040, when the closure barrier becomes effective. This set of simulations was performed to investigate the sensitivity of the Case 1 results to moderate variations in the inventory distribution.

Solute BTCs at the first compliance point for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Attachment E3, Figures E3.166 through E3.174 for the three solute species (technetium-99, chromium, and nitrate), respectively. Aqueous flux at the water table for the three cross-sections (S-CC', SX-DD', and SX-FF') are shown in Figures E3.175 through E3.177, respectively. Times and aqueous concentrations for the BTC peaks at the first compliance boundary are shown in Table E.29. Area-weighted averages (across the three cross-sections) of the solute BTCs were generated for the three solute species, as shown in Attachment E3, Figures E3.178 through E3.180 for technetium-99, chromium, and nitrate, respectively. When peak arrival concentration was weighted by maximum initial concentration, the breakthrough concentrations of the alternate distribution varied from those for the uniform distribution (i.e., Case 1 simulation) by 9.7 to 81.6%, depending on the solute. The results provide an indication of variations in peak arrival concentrations with uncertainty in the areal location of the initial inventory.

Table E.29. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 12

Parameter	S-CC'	SX-DD'	SX-FF'
Tc-99			
Arrival Time	2032.3 yr	2050.3 yr	2032.6 yr
Peak Conc.	1.346×10^5 pCi/L	5.857×10^5 pCi/L	3.132×10^5 pCi/L
Max. Initial Conc.*	3.959×10^6 pCi/L	3.463×10^7 pCi/L	7.515×10^6 pCi/L
Cr			
Arrival Time	2050.7 yr	2052.7 yr	2051.3 yr
Peak Conc.	2.661×10^3 µg/L	4.453×10^4 µg/L	3.829×10^3 µg/L
Max. Initial Conc.	1.107×10^5 µg/L	1.847×10^6 µg/L	1.220×10^5 µg/L
NO_3			
Arrival Time	2031.9 yr	2050.3 yr	2031.3 yr
Peak Conc.	5.988×10^5 µg/L	8.148×10^5 µg/L	5.137×10^5 µg/L
Max. Initial Conc.	1.714×10^7 µg/L	3.678×10^7 µg/L	1.173×10^7 µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

E.4.13 NO BARRIER AND 200,000 GAL WATER-LINE LEAK CASE (CASE 13)

The no barrier and 200,000 gal water-line leak suite of simulations, Case 13, investigated solute transport through one cross-section considering natural surface infiltration and a closure barrier by the year 2040. This suite of simulations differs from the Case 1 simulations in that a water-line leak occurs for tank SX-115 in cross-section SX-FF'. The water-line leak was modeled as a point source of water (200,000 gal over a 5-day period) spread over a 15 ft radius between tanks SX-114 and SX-115. The 15 ft radius leak area was translated to the two-dimensional simulation by using a computational grid width of 1 ft and assuming that the center of the circular leak area was situated on the center line between tanks. This approach results in a two-dimensional water-line leak of 8,488 gal over a 5-day period. These simulations were initialized using a steady-flow solution defined by the surface recharge rate of 100 mm/yr and a hydraulic gradient in the unconfined aquifer. Inventories of the four contaminant species were initialized using the uniform distribution pattern. Plot-file output for these simulations was generated at the years 2000, 2000.0137, 2000.0274, 2000.0685, 2000.137, 2000.5, 2001, 2040, 2540, and 3000 and include values for the aqueous saturation, aqueous pressure, aqueous moisture content, and concentrations for the four solute species.

The flow environment following the leak event is shown in a series of color-scaled images of aqueous saturation at 5, 10, 25, 50, 183, and 365 days after the leak in Figures E.23 through E.28, respectively. After 5 days (Figure E.23), the 200,000 gal leak has completely saturated the backfill material between tanks SX-114 and SX-115, with a portion of the saturated zone extending above the tank dome and below the tank bottom. After 10 days (Figure E.24), the

leak-water has descended into the coarser grained gravelly-sand strata. At 25 and 50 days (Figures E.25 and E.26), the leak has passed through and migrated along the gravelly-sand strata, crossed the tanks SX-114 and SX-115 domes, and started to form perched water above the Plio-Pleistocene strata. Between 50 days and 1 year (Figures E.27 and E.28), the leak plume descended through the Plio-Pleistocene strata, reached the groundwater, and formed two auxiliary plumes from the leak water that crossed the tank domes. After one year, the saturation field had not returned to steady-flow conditions (Figure E.28). This result differs from the 25,000 gal leak, where the saturation field had returned to steady-flow conditions after 1 year.

Figure E.23. Case 13 Aqueous-Phase Saturation at 2000 plus 5 days for Cross-Section SX-FF'

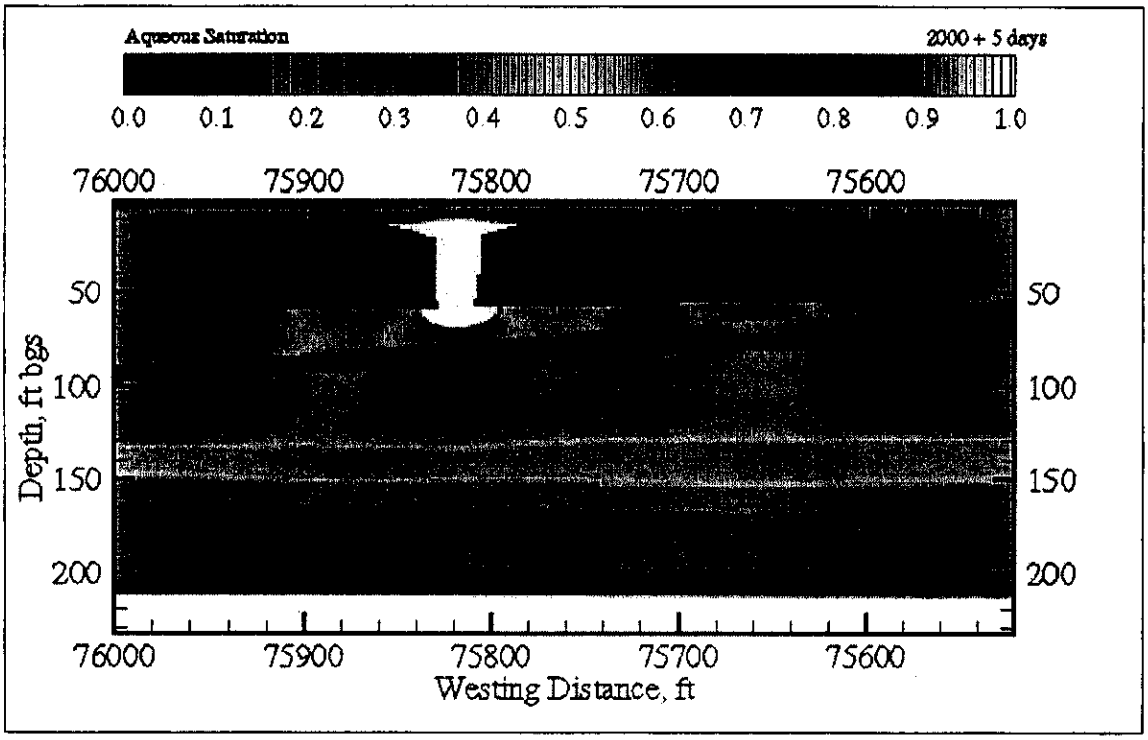


Figure E.24. Case 13 Aqueous-Phase Saturation at 2000 plus 10 days for Cross-Section SX-FF'

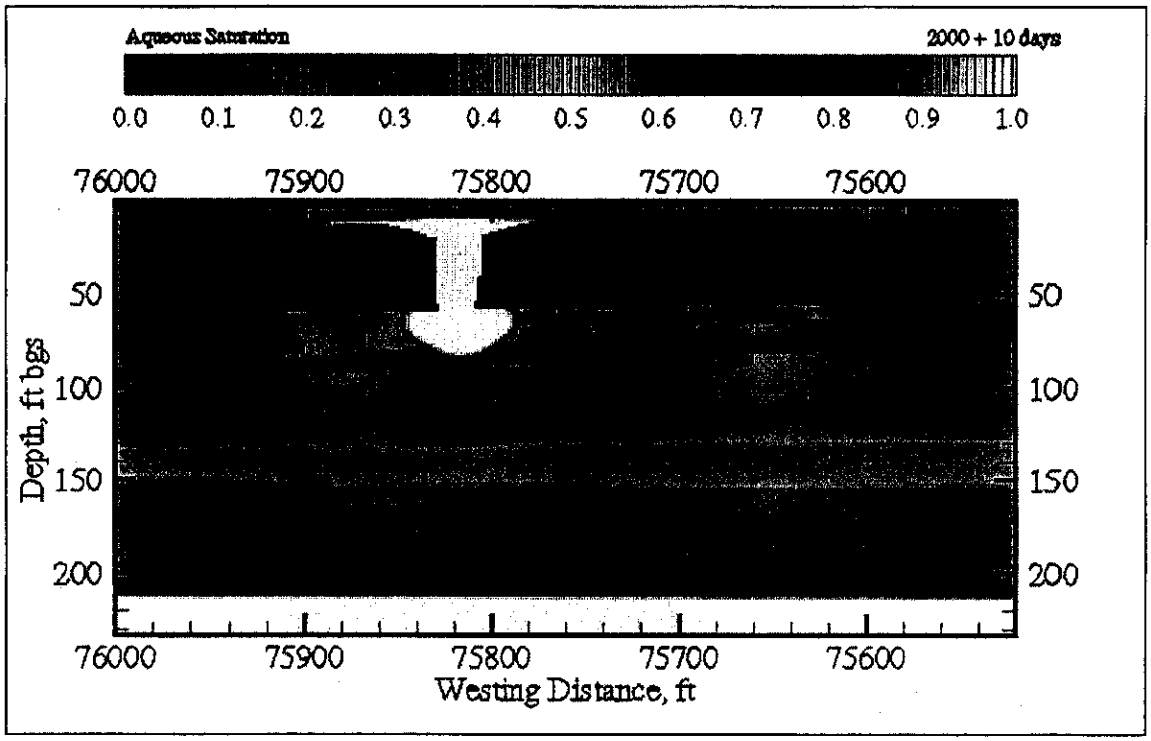


Figure E.25. Case 13 Aqueous-Phase Saturation at 2000 plus 25 days for Cross-Section SX-FF'

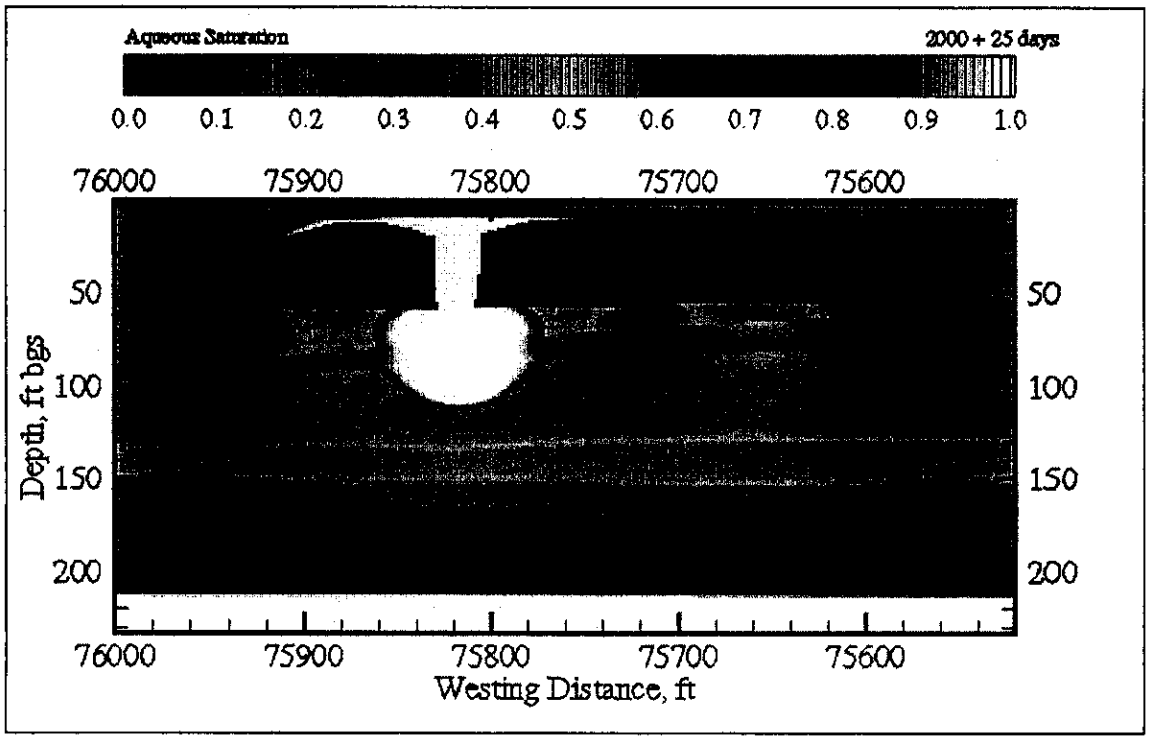


Figure E.26. Case 13 Aqueous-Phase Saturation at 2000 plus 50 days for Cross-Section SX-FF'

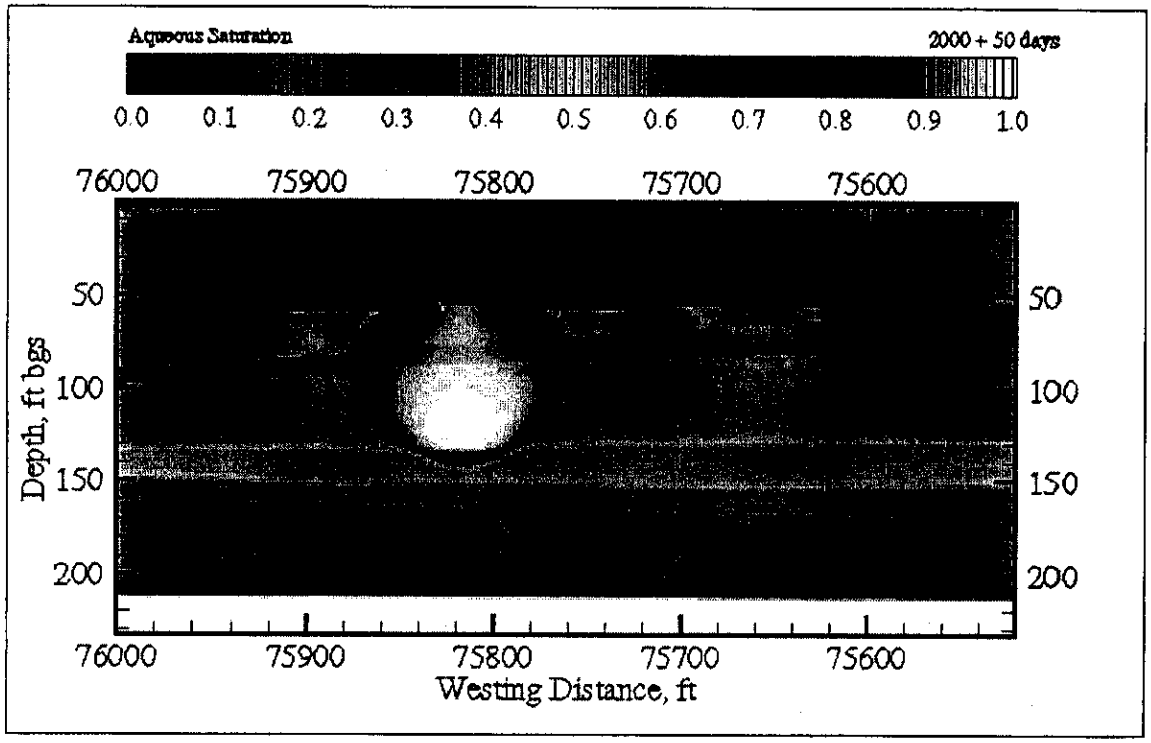


Figure E.27. Case 13 Aqueous-Phase Saturation at 2000 plus 183 days for Cross-Section SX-FF'

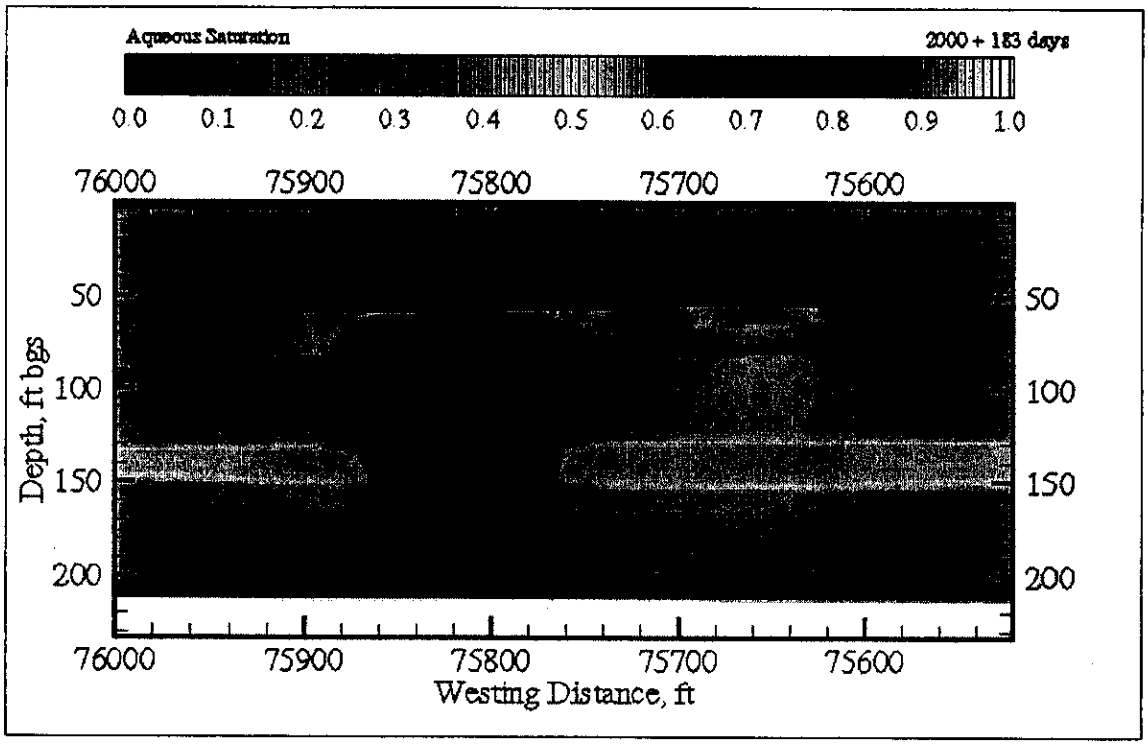
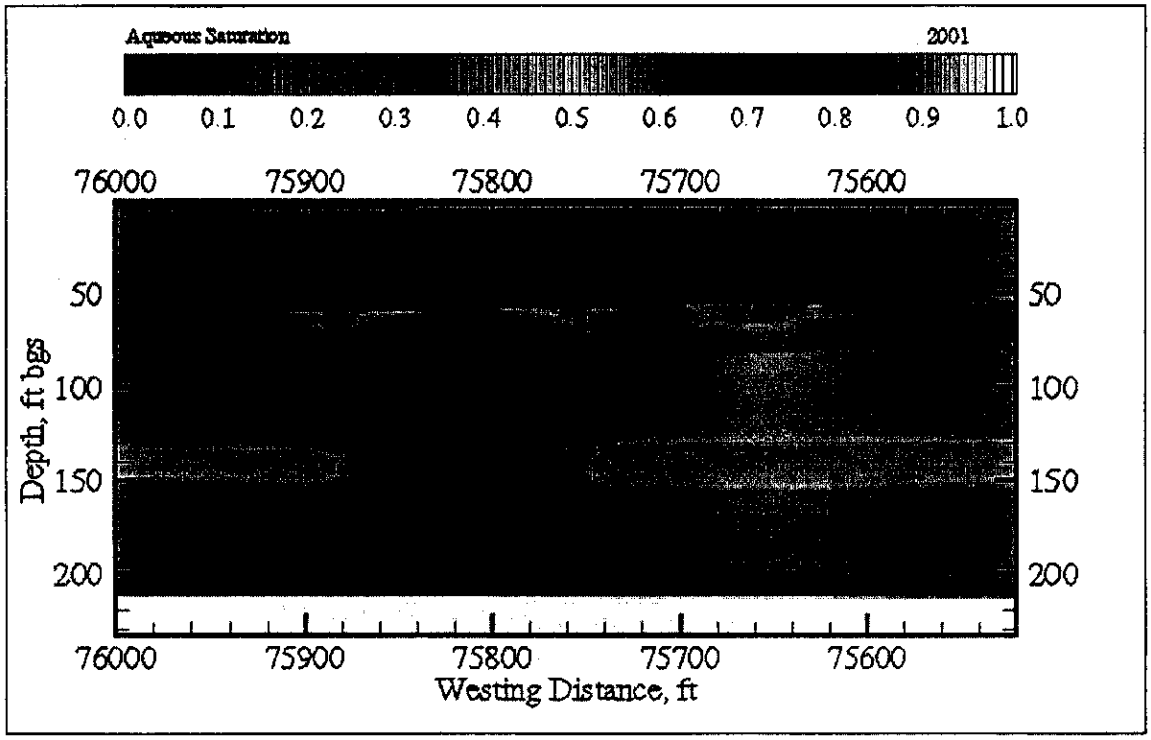


Figure E.28. Case 13 Aqueous-Phase Saturation at 2000 plus 365 days for Cross-Section SX-FF'



Solute BTCs at the first compliance point for cross-section SX-FF' are shown in Attachment E3, Figures E3.187 through E3.189 for the three solute species (technetium-99, chromium, and nitrate), respectively. BTCs for cross-sections S-CC' and SX-DD' are shown in Figures E3.181 through E3.186. Aqueous fluxes at the water table for the three cross-sections are shown in Figures E3.190 through E3.192. Peak concentrations and arrival times for the BTCs at the first compliance boundary are shown in Table E.30. Area-weighted averages of the solute BTCs were generated for the three solute species and are shown in Attachment E3, Figures E3.193 through E3.195 for technetium-99, chromium, and nitrate, respectively. The saturation fields (Figures E.23 through E.28) showed saturation around the tank domes and the leak plumes rapidly descending through various strata. However, the BTCs at the WMA S-SX boundary suggest only slight differences in shapes and arrival concentrations (Attachment E3, Figures E3.187 through E3.189). Arrival times for the solutes in cross-section SX-FF' were advanced by approximately three years, but the peak concentrations were decreased, compared against the Case 1 and Case 3. Decreases in peak concentrations were a direct result of dilution due to the leak event.

Table E.30. Peak Concentrations and Arrival Times at the First Compliance Point (i.e., WMA S-SX Boundary) for Case 13

Parameter	SX-FF'
Tc-99	
Arrival Time	2027.5 yr
Peak Conc.	2.445×10^5 pCi/L
Max. Initial Conc.*	5.074×10^6 pCi/L
Cr	
Arrival Time	2049.3 yr
Peak Conc.	4.323×10^3 µg/L
Max. Initial Conc.	1.089×10^5 µg/L
NO_3	
Arrival Time	2028.5 yr
Peak Conc.	9.522×10^5 µg/L
Max. Initial Conc.	3.616×10^7 µg/L

*Maximum initial concentration is based on inventory data (Section E.2.4.3) and listed for comparison with the simulated peak concentration at the compliance boundary.

The impact on the transport of contaminants of the 200,000 gal leak event is shown by comparing the distribution of technetium-99 at 2001 and 2040 (Figures E.29 and E.30). By 2001, the technetium-99 concentration field has been deformed toward the water table within the leak-plume column. This deformation alters the shape of the BTC (Attachment E3, Figure E3.187), but the undisturbed regions of the technetium-99 plume, outside of the leak-plume column, descend in response to the rate of meteoric recharge over a 40-year period. The similarity in technetium-99 plumes for 2040 below tanks SX-113 and SX-115 (Figure E.30) shows this effect.

Figure E.29. Case 13 Technetium-99 Aqueous Concentration at 2001 for Cross-Section SX-FF'

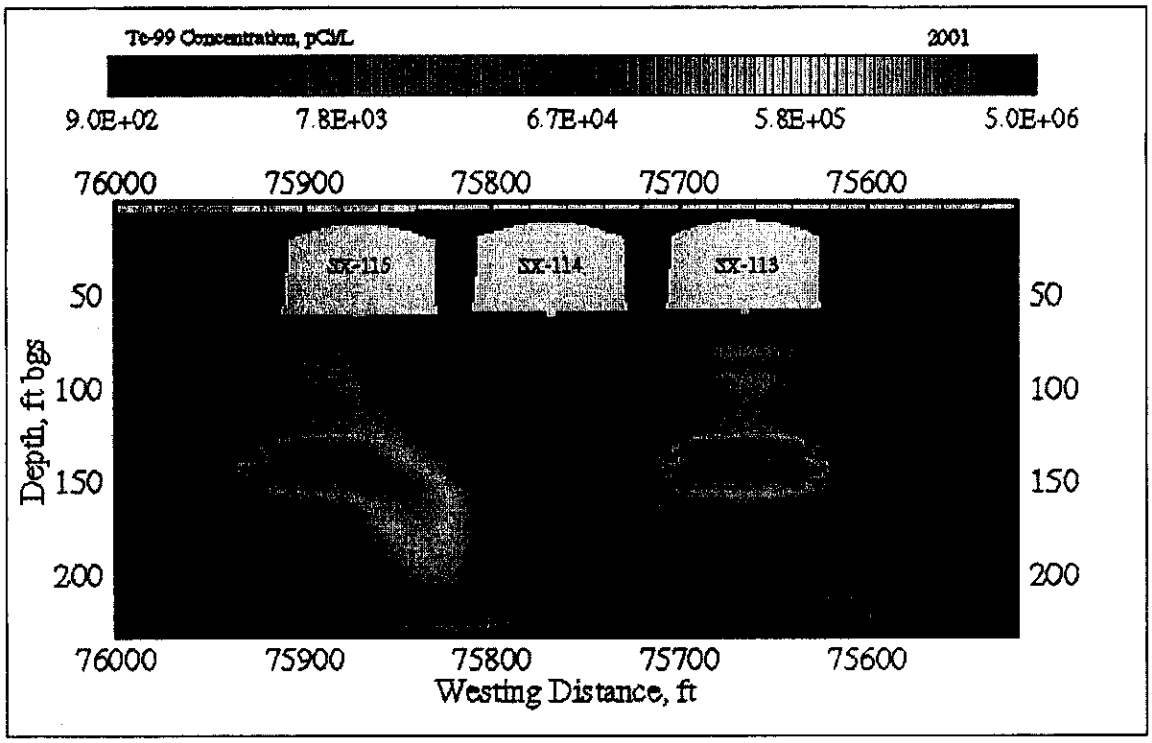
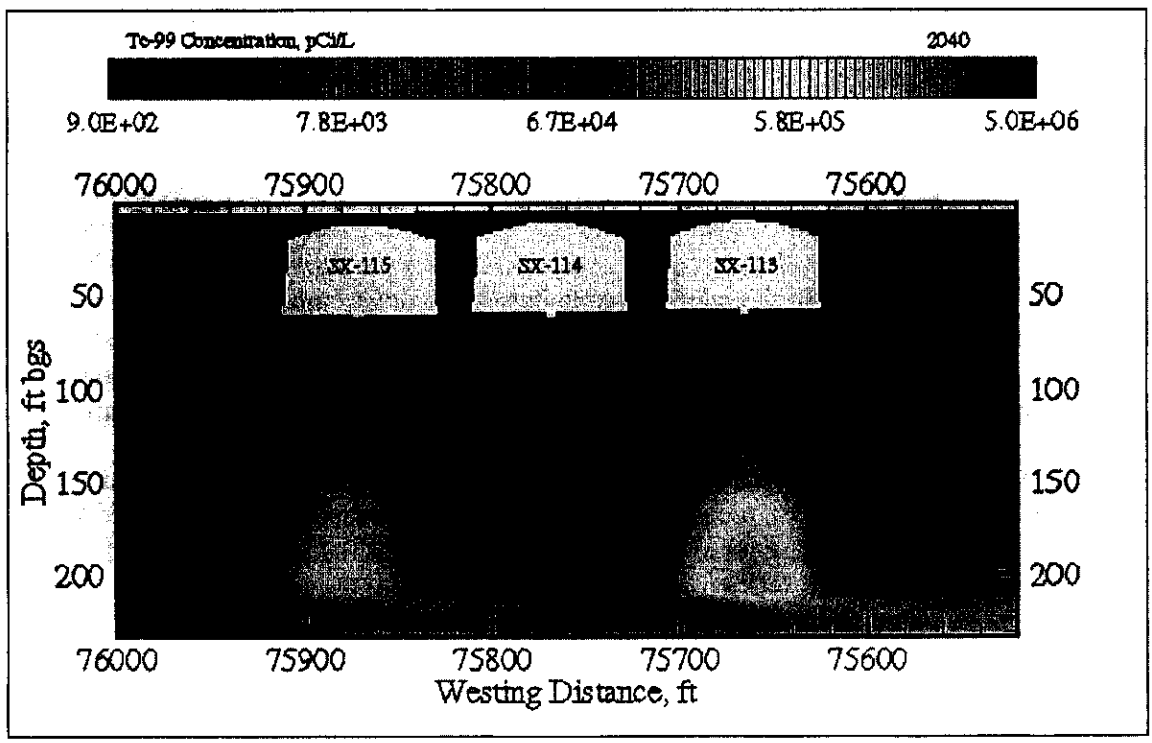


Figure E.30. Case 13 Technetium-99 Aqueous Concentration at 2040 for Cross-Section SX-FF'



E.4.14 THREE-DIMENSIONAL SIMULATIONS

The objective of this suite of simulations is to determine the differences in results between the simulations constrained along a two-dimensional cross-section compared to the results of a simulation extended to three dimensions. Specifically, the two-dimensional cross-section simulations are along the maximum diameter of the rows of tanks, focusing the recharge over the cross-section within the most narrow zones between the tanks.

A three-dimensional simulation was constructed from a one-quarter section around tank SX-108 (Attachment E3, Figure E3.196). The geology around the tank (from east/west cross-section SX-DD' in the x and z directions) and inventory were duplicated and extended toward the north (i.e., y-direction). The radial extent of the cross-section extends to the midpoint between tanks SX-108 and SX-109 to the west and between tank SX-105 to the north. Attachment E3, Figure E3.197 shows the zonations along the southern-most y-plane, which has the maximum radius of the tank (i.e., the same plane used in the two-dimensional simulations). Transient simulations were conducted using the inventory and recharge rates from Case 1 with the three-dimensional domain and with a two-dimensional domain along the southern-most y-plane for direct comparison of results. The tank SX-108 three-dimensional simulation domain consisted of 119,422 nodes (x,y,z = 29 × 29 × 142 nodes). Within this domain, approximately 12,000 nodes were inactive, representing the tank itself. The three-dimensional simulation execution time was approximately 5 days for a 1,000-year simulation (0.333 year time step) running on a 600-Mhz Pentium II processor with 256 MB RAM.

Attachment E3, Figure E3.198 shows the steady-flow volumetric water flux vectors in the x-z directions for three y-planes (front, middle, and back) within the three-dimensional domain from the 100 mm/yr recharge rate used for the first 40 years. These vectors illustrate the umbrella-effect of the tanks, where the recharge sheds from the top of the tank. The highest water fluxes occur in the thinnest zone on the front plane (i.e., y=1). Directly below the tank, the vectors show water moving back under the tank. Variations in the water fluxes near the tanks are dampened out towards the bottom of the domain resulting in a relatively uniform flow field in the lower half. The impact of the geology is also illustrated in Figure E3.198 where the vectors are refracted from the sloping bottom contact of Unit 3 (gravelly sand/sandy gravel) at a depth of 24.4 to 30.5 m (80 to 100 ft) below ground surface. Volumetric water fluxes are shown in the x-y directions at 4 different depths (z-planes) around the tanks in Figures E3.199 and E3.200. These figures show relatively high water fluxes in the x-y direction moving away from the tanks across upper dome (Figure E3.199) and moving back under the tanks below the bottom (Figure E3.200). At depths between the upper dome and bottom of the tank, water fluxes are dominantly vertical (z-direction) and very low in the x-y plane (see Figures E3.199 and E3.200).

Figure E3.201 shows the aqueous saturation along three different planes (front, middle, and back) in the y-direction at the beginning of the simulation (i.e., year 2000 with 100 mm/yr recharge). The impact of the tank on aqueous saturations can still be seen on the back (northern-most) y plane, which is 3 m (10 ft) north of the edge of the tank. Figure E3.202 shows the results of the technetium-99 plume along three y-planes by year 2040 (compare to initial conditions in Figure E3.197). Figure E3.203 shows a comparison of the technetium-99 mass fluxes at the bottom of the domain for nodes on the east, center, and west of the two y-planes on

the north and south of the domain (y=1 and y=29). No variation was seen in the water fluxes for these nodes.

A comparison of the water and technetium-99 fluxes at the bottom of the simulation domain between the three-dimensional tank SX-108 and two-dimensional tank SX-108 simulations is shown in Figures E3.204 and E3.205. These figures compare the two-dimensional simulation results with the three-dimensional results from the front plane and the average over the entire three-dimensional domain. These data were scaled to unit widths. The results show little difference between the water fluxes over the 1,000-year duration of these simulations (Figure E3.204). While the simulated mass fluxes were similar overall, the peak technetium-99 mass fluxes (around year 2050) were slightly higher in the three-dimensional simulation than for the two-dimensional simulation. The peak technetium-99 mass flux for the front plane (y=1) of the three-dimensional simulation was also slightly higher than the mass flux average for the entire three-dimensional domain.

E.4.15 SOLUTE MASS BALANCE

Mass balance checks were performed on the non-decaying solutes (i.e., nitrate and chromium) for each combination of simulation case and cross-section, using Equation E.18.

$$m_{error} = \frac{m_{initial} - m_{final} - m_{exiting}}{m_{initial}} \qquad \text{(E.18)}$$

where:

m_{error} = mass balance error, expressed in percent
$m_{initial}$ = initial solute inventory computed from the STOMP plot-file output at the year 2000
m_{final} = final solute inventory computed from the STOMP plot-file output at the year 3000
$m_{exiting}$ = integrated solute inventory leaving the computation domain, computed from the STOMP surface-flux output.

Initial and final solute masses were computed using a two-step process: (1) STOMP plot-file outputs were converted to two-dimensional Tecplot format using the utility PlotTec; (2) solute mass was integrated using the Tecplot statistical tools package. The solute mass leaving the computational domain through the groundwater was determined using surface-flux output, defined for the western surfaces below the water table. The surface-flux output provided both the solute-flux rate and integral. Other than solving the solute mass conservation equations, the STOMP simulator contains no algorithms for correcting local or global mass. Therefore, mass balance errors, reported below represent the actual mass balance errors from the conservation equations. Mass balance errors, expressed as percent error, are shown in Table E.31 for the non-decaying species nitrate and chromium. The average mass balance error for the simulations without concentration dependent density and viscosity was 1.90×10^{-5} % and for those simulations with concentration dependent density and viscosity was 5.48×10^{-2} %.
The simulations with concentration dependent density and viscosity showed higher mass balance errors, because of the loose coupling between the aqueous-phase flow properties and the solute

concentrations. This level of error in the conservation of solute mass, indicates that a fully coupled solution approach was not needed for the investigated simulations.

Table E.31. Solute Mass Balance Errors

m_{error}	Cross-Section S-CC'		Cross-Section SX-DD'		Cross-Section SX-FF'	
%	Cr	NO_3	Cr	NO_3	Cr	NO_3
Case 1	4.75×10^{-6}	5.52×10^{-6}	1.48×10^{-5}	3.94×10^{-6}	3.65×10^{-7}	5.69×10^{-6}
Case 2	1.33×10^{-5}	1.68×10^{-5}	2.06×10^{-7}	1.09×10^{-5}	5.33×10^{-6}	1.29×10^{-5}
Case 3	4.75×10^{-6}	5.52×10^{-6}	1.48×10^{-5}	3.94×10^{-6}	1.39×10^{-5}	5.76×10^{-6}
Case 5	3.03×10^{-5}	1.01×10^{-5}	4.03×10^{-5}	3.25×10^{-5}	5.94×10^{-5}	4.13×10^{-6}
Case 6	2.97×10^{-7}	2.18×10^{-5}	2.91×10^{-5}	4.49×10^{-5}	2.87×10^{-5}	1.12×10^{-5}
Case 7	6.65×10^{-5}	1.41×10^{-5}	4.03×10^{-5}	3.21×10^{-5}	1.32×10^{-5}	1.11×10^{-5}
Case 8	4.56×10^{-2}	2.19×10^{-2}	9.83×10^{-2}	9.04×10^{-2}	5.06×10^{-2}	2.20×10^{-2}
Case 9	2.46×10^{-7}	1.80×10^{-5}	2.07×10^{-5}	4.32×10^{-6}	4.32×10^{-5}	2.44×10^{-5}
Case 10	1.77×10^{-6}	2.23×10^{-5}	5.89×10^{-5}	3.76×10^{-6}	2.02×10^{-5}	1.42×10^{-5}
Case 11	9.80×10^{-6}	4.78×10^{-6}	1.95×10^{-4}	1.79×10^{-5}	5.23×10^{-5}	8.15×10^{-6}
Case 12	4.56×10^{-6}	1.05×10^{-5}	1.57×10^{-5}	1.05×10^{-5}	1.97×10^{-5}	3.28×10^{-6}
Case 13	4.75×10^{-6}	5.52×10^{-6}	1.48×10^{-5}	3.94×10^{-6}	1.12×10^{-6}	4.12×10^{-6}

E.5.0 STREAMTUBE MODELING RESULTS

An analytical streamtube model was used to route the simulated WMA S-SX average concentrations for each case to three compliance locations: 200 West Area fence, 200 Area exclusion boundary (located approximately 1.25 km [0.78 mi] east of the 200 East Area), and the Columbia River. The analytic streamtube model was based on an approach described by Baetsle (1969), as documented in Freeze and Cherry (1979). The streamtube model assumes transport from a point source, represented by a series of solute slugs, and considers longitudinal, lateral, and transverse vertical dispersion; molecular diffusion; and first order decay. The method of superposition was used to integrate the individual slug sources.

Distances and travel times from WMA S-SX to the three compliance points were derived from steady-state VAM3D unconfined aquifer flow simulations of the Hanford Site (Lu 1996). The simulation results represent 'post-Hanford' or future conditions representing the water table at the Site without the additional impact of any unconfined aquifer discharges. Results of the VAM3D simulated hydraulic heads and streamlines are shown in Figures E.5 and E.6; these figures are based on Lu (1996). Two streamlines from Figure E.6 starting at S tank farm and SX tank farm were used to determine the unconfined aquifer path length to the three compliance points. Travel markers indicating 20-year intervals on the streamlines were used to estimate the travel time to the three compliance points. The two streamlines (for S and SX tank farms) had similar lengths and travel times to the compliance points, resulting in only one estimate for WMA S-SX (see Table E.32). Both of these streamlines move roughly east from WMA S-SX toward the Columbia River on the south side of Gable Mountain. Other groundwater flow simulations of the Hanford Site have shown the potential for a different pathline from WMA S-SX that goes northward through the Gable Mountain/Gable Butte gap. These pathlines were not considered in this analysis.

Table E.32. Distances and Travel Times from WMA S-SX

Compliance Point	Distance (mi)	Time (yrs)
200 West fence	1.12	140
Exclusion Boundary	6.52	300
Columbia River Shoreline	14.0	500

Note: Derived from flow lines and 20-year travel markers from post-Hanford simulation (Section E.2.3.1).

Given the large variation in groundwater velocities between the three compliance points (see Table E.33), three streamtubes were constructed representing the aquifer between WMA S-SX and each compliance point. Solute mass flux across WMA S-SX boundary was a composite of the simulated aquifer outlet mass fluxes from the S-CC', SX-DD', and SX-FF' cross-sections and was converted into slugs of mass as input to the analytical streamtube model. Groundwater velocities for each streamtube are constant.

Table E.33. Streamtube Characteristics

From	To	Distance (mi)	Velocity (ft/day)
WMA S-SX	200 West fence	1.12	0.116
200 West fence	Exclusion boundary	5.40	0.488
Exclusion boundary	Columbia River	7.48	0.541

A FORTRAN program was written to implement the mass flux conversion to time varying solute slugs, the analytical solution of Baetsle (1969), and superpositioning of the time-varying mass fluxes. The BTCs for each case and each species (i.e., technetium-99, chromium, and nitrate) were calculated from the streamtube fro each compliance boundary, using the FORTRAN program.

The two-dimensional transport simulations (Section E.3.0) yielded solute mass flux and concentration at the WMA S-SX boundary along the tank centerlines for the three cross-sections (S-CC', SX-DD', and SX-FF'), as shown in Figure E.31. Translation of the centerline solute mass flux or concentration to an average value across the WMA boundary was computed using two translations. In the first translation, the centerline quantities are converted to average quantities on the WMA boundary line within the regions shown in Figure E.31 as the cross-section projections. The length of the cross-section projection equals the mean inventory diameter, where the mean inventory diameter was computed for each combination of solute specie and concentration, as described in the inventory section (Section E.2.4.3). As shown graphically in Figure E.31, the mean inventory diameter is *not* the tank diameter.

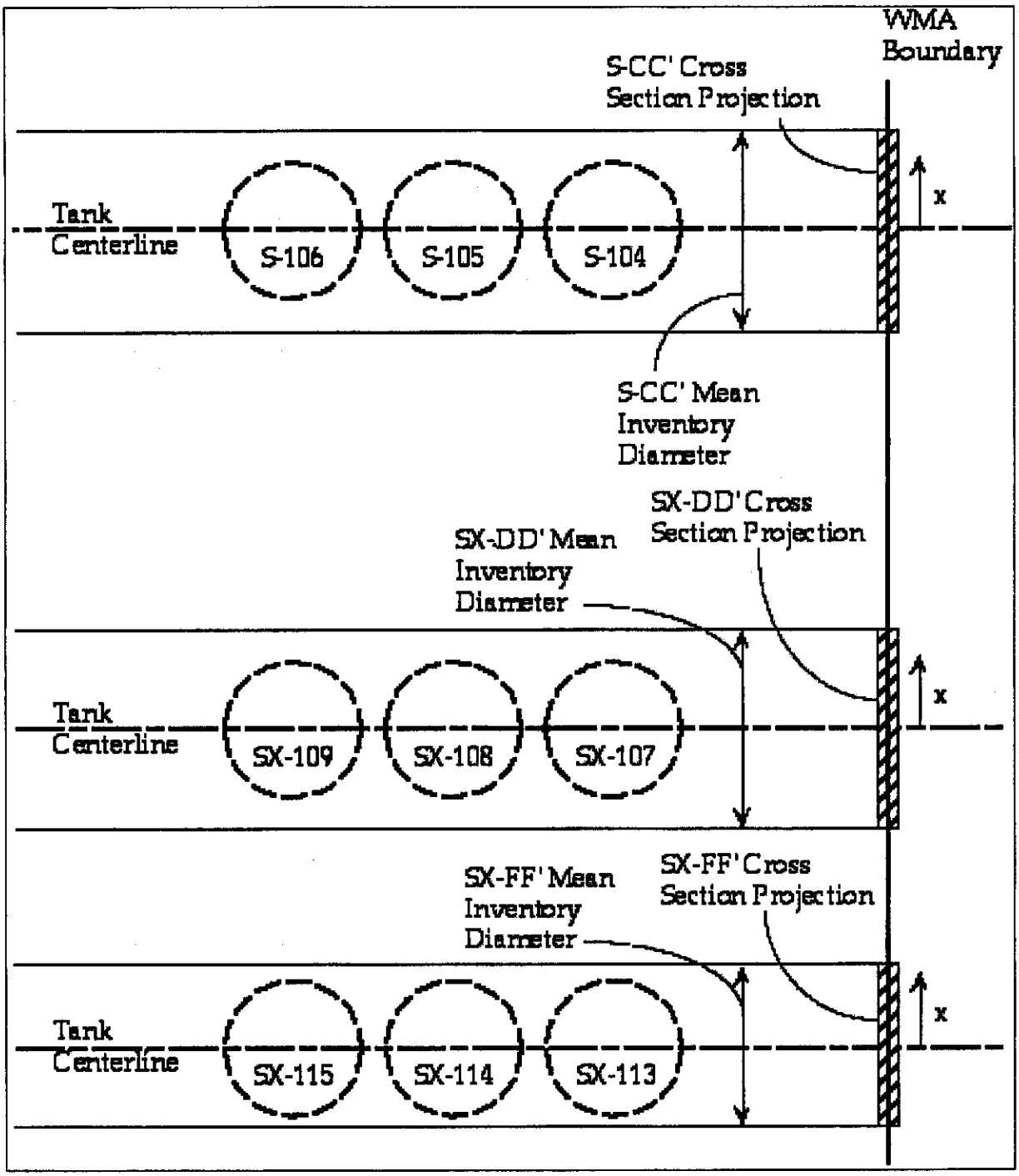
Off centerline solute mass flux and concentration are computed by assuming the concentration distribution shown in Equation E.19.

$$C_\ell(x) = \hat{C}_\ell \frac{l_c(x)}{\langle D \rangle} = \hat{C}_\ell \frac{\sqrt{\langle D \rangle^2 - 4x^2}}{\langle D \rangle} \qquad \text{(E.19)}$$

where:

$C_\ell(x)$ = solute mass flux or concentration as a function of distance x along the WMA boundary
$\hat{C}_\ell$ = tank centerline solute mass flux or concentration
$l_c(x)$ = chord length across the mean inventory circle as a function of distance x along the WMA boundary
$\langle D \rangle$ = mean inventory diameter
x = distance from the tank centerline along the WMA boundary.

Figure E.31. Translation Geometry



The average solute mass flux or concentration is computed by integrating Equation E.19, as shown in Equation E.20.

$$\tilde{C}_\ell = \hat{C}_\ell \int_0^{\langle D \rangle / 2} \frac{2\sqrt{\langle D \rangle^2 - 4x^2}}{\langle D \rangle^2} dx = \hat{C}_\ell \frac{\pi}{4} \qquad \text{(E.20)}$$

where:

$\tilde{C}_\ell$ = average solute mass flux or concentration along the WMA boundary within the cross-section projection.

An average solute mass flux or concentration is computed according to Equation E.20 for the three cross-sections (i.e., $\tilde{C}_\ell^{scc'}$ for S-CC', $\tilde{C}_\ell^{sxdd'}$ for SX-DD', and $\tilde{C}_\ell^{sxff'}$ for SX-FF').

The three cross-sectional average solute mass fluxes or concentrations are translated to a single average solute mass flux or concentration for the entire WMA S-SX boundary length using length-weighted averaging according to Equation E.21.

$$\overline{C}_\ell = \sum_{i = scc', sxdd', sxff'} \frac{\langle D^i \rangle}{L_{WMA}} \tilde{C}_\ell^i \qquad \text{(E.21)}$$

where:

$\overline{C}_\ell$ = average solute mass flux or concentration for the WMA boundary

$\langle D^i \rangle$ = mean inventory diameter for cross-section i

L_{WMA} = north-south length of the WMA S-SX boundary.

Results of the streamtube analyses are summarized in Tables E.34 through E.36, showing the peak time (year) and peak concentration for each case and compliance location, for the three species (technetium-99, chromium, and nitrate), respectively. Peak concentrations and times are a direct result of the superposition of mass fluxes from cross-sections S-CC', SX-DD', and SX-FF' averaged over the fence-line of the WMA.

Table E.34. Streamtube Analysis Summary for Technetium-99

Tc-99 Conc.	WMA S-SX		200 West fence		Exclusion Boundary		Columbia River	
(pCi/L)	Time	Conc.	Time	Conc.	(pCi/L)	Time	Conc.	Time
Case 1	2046	6.85E+04	2181	4.89E+03	2344	3.80E+02	2545	1.28E+02
Case 2	2030	2.90E+04	2179	1.91E+03	2341	1.47E+02	2543	5.11E+01
Case 3	2046	6.74E+04	2180	4.89E+03	2344	3.79E+02	2545	1.29E+02
Case 4	2046	6.83E+04	2181	4.89E+03	2344	3.79E+02	2545	1.28E+02
Case 5	2044	7.49E+04	2179	5.29E+03	2342	4.11E+02	2543	1.39E+02
Case 6	2029	3.44E+04	2178	2.09E+03	2340	1.62E+02	2542	5.61E+01
Case 7	2011	1.71E+05	2149	6.89E+03	2314	5.42E+02	2514	1.78E+02
Case 8	2046	6.92E+04	2180	4.96E+03	2344	3.85E+02	2545	1.30E+02
Case 9	2061	3.53E+04	2203	2.50E+03	2365	1.91E+02	2567	6.67E+01
Case 10	2075	1.74E+04	2223	1.32E+03	2384	9.97E+01	2586	3.54E+01
Case 11	3000*	4.34E+03	2312	3.08E+02	2471	2.26E+01	2673	8.28E+00
Case 12	2046	6.87E+04	2180	4.95E+03	2344	3.84E+02	2545	1.30E+02
Case 13	2047	6.31E+04	2179	4.76E+03	2342	3.68E+02	2543	1.25E+02

Note: Groundwater limit 900 pCi/L.
*Peak concentrations arrive after year 3000.

Table E.35. Streamtube Analysis Summary for Chromium

Cr Conc.	WMA S-SX		200 West fence		Exclusion Boundary		Columbia River	
(μg/L)	Time	Conc.	Time	Conc.	(μg/L)	Time	Conc.	Time
Case 1	2052	7.33E+03	2191	4.49E+02	2354	3.49E+01	2556	1.19E+01
Case 2	2057	1.02E+03	2210	8.55E+01	2370	6.44E+00	2573	2.31E+00
Case 3	2052	7.34E+03	2191	4.52E+02	2354	3.51E+01	2555	1.20E+01
Case 4	2052	7.30E+03	2191	4.47E+02	2354	3.48E+01	2556	1.18E+01
Case 5	2051	8.71E+03	2188	5.23E+02	2351	4.08E+01	2552	1.38E+01
Case 6	2051	1.29E+03	2205	1.03E+02	2365	7.76E+00	2568	2.77E+00
Case 7	2017	1.49E+04	2157	7.78E+02	2321	6.09E+01	2522	2.02E+01
Case 8	2052	7.42E+03	2191	4.55E+02	2354	3.54E+01	2555	1.20E+01
Case 9	2074	2.04E+03	2226	1.54E+02	2386	1.17E+01	2589	4.14E+00
Case 10	2119	6.38E+02	2272	5.55E+01	2430	4.11E+00	2632	1.50E+00
Case 11	3000*	3.86E+02	3000*	7.27E+00	2771	5.13E-01	2972	1.89E-01
Case 12	2052	7.28E+03	2191	4.51E+02	2354	3.51E+01	2555	1.19E+01
Case 13	2052	7.20E+03	2189	4.55E+02	2353	3.53E+01	2554	1.20E+01

Note: Groundwater limit 50 μg/L.
*Peak concentrations arrive after year 3000.

Table E.36. Streamtube Analysis Summary for Nitrate

NO_3 Conc.	WMA S-SX		200 West fence		Exclusion Boundary		Columbia River	
(μg/L)	Time	Conc.	Time	Conc.	Time	Conc.	Time	Conc.
Case 1	2041	1.28E+05	2178	9.49E+03	2342	7.37E+02	2542	2.49E+02
Case 2	2029	6.88E+04	2177	4.31E+03	2339	3.34E+02	2541	1.15E+02
Case 3	2041	1.27E+05	2178	9.50E+03	2341	7.38E+02	2542	2.50E+02
Case 4	2041	1.28E+05	2178	9.46E+03	2342	7.35E+02	2542	2.49E+02
Case 5	2038	1.39E+05	2176	1.02E+04	2340	7.96E+02	2540	2.69E+02
Case 6	2027	8.41E+04	2175	4.81E+03	2337	3.73E+02	2539	1.29E+02
Case 7	2007	3.57E+05	2148	1.31E+04	2312	1.03E+03	2513	3.39E+02
Case 8	2041	1.29E+05	2178	9.61E+03	2341	7.47E+02	2542	2.52E+02
Case 9	2058	7.76E+04	2199	5.32E+03	2361	4.09E+02	2563	1.42E+02
Case 10	2074	4.12E+04	2221	3.04E+03	2382	2.31E+02	2584	8.17E+01
Case 11	2167	8.45E+03	2315	7.45E+02	2473	5.48E+01	2676	2.01E+01
Case 12	2039	1.28E+05	2177	9.63E+03	2340	7.48E+02	2541	2.53E+02
Case 13	2041	1.21E+05	2177	9.42E+03	2340	7.30E+02	2541	2.48E+02

Note: Groundwater limit 45,000 μg/L.
*Peak concentrations arrive after year 3000.

The first streamtube extended from the WMA boundary to the 200 West fence compliance boundary; peak concentrations at the 200 West fence generally decreased to less than 10% of the WMA boundary concentration. Those simulations with broader BTCs at the WMA boundary had lower percent decreases; whereas, those with sharper BTCs had greater percent decreases from longitudinal dispersion. The second streamtube extended from the 200 West fence to the 200 Area exclusion boundary. Again, the concentrations at the 200 Area exclusion boundary generally decreased to less than 10% of the 200 West fence boundary concentration. Results for the final streamtube (between the 200 Area exclusion boundary and Columbia River) showed the smallest decrease in peak concentrations for all the streamtubes, even though the residence time in this streamtube was the longest. The peak concentrations at the Columbia River boundary generally decreased to less than 40% of the 200 Area exclusion boundary concentration.
The reason for the lower percentage decrease in concentrations for this streamtube is that the peak concentrations have already been significantly attenuated by the earlier two streamtubes resulting in larger and broader pulses. The increase in unconfined aquifer velocity accounted for most of the decrease in peak concentrations for this streamtube.

E.6.0 HUMAN HEALTH RISK AND DOSE RESULTS

This section presents the results of the human health risk and dose assessment. The risk and dose values presented are based on the groundwater concentrations generated through contaminant transport modeling (Sections E.1.0 and E.2.0) and were calculated using the approach described in Section E.3.0. Groundwater concentration values from cross-sections S-CC', SX-DD', and SX-FF' at the WMA S-SX boundary used Equation E.19 in Section E.5.0 to calculate the risk and dose values with the methodology described in Section E.3.0. Note that risk and dose results are presented only for a select group of simulation cases (Table E.37). Results for these cases are representative of the larger set of cases considered in the contaminant transport analysis and include information on the impacts associated with existing conditions (Case 1); interim barrier use (Case 2); and variable meteoric recharge rates (Cases 9, 10, 11). The remaining cases generally represent variations around the existing conditions or interim barrier cases and are not specifically discussed in this section because their impacts are of similar magnitude to either Case 1 or 2.

Table E.37. Human Health Risk and Dose Assessment Cases

Case	Description	Rationale
1	Base case (no action alternative)	Reference case. Estimation of impacts from past contaminant releases at WMA S-SX if no interim measures or interim corrective measures were implemented.
2	Barrier alternative and no water-line leaks	Interim corrective measure case. Estimation of degree to which implementation of an interim surface barrier would decrease impacts from past contaminant releases at WMA S-SX.
9	Base case with 50 mm/yr meteoric recharge	Meteoric recharge sensitivity cases. Estimation of degree to which meteoric recharge modeling assumptions affect estimated base case impacts from past contaminant releases at WMA S-SX.
10	Base case with 30 mm/yr meteoric recharge	
11	Base case with 10 mm/yr meteoric recharge	

WMA = waste management area.

Risk and dose results for the five cases shown in Table E.37 are presented individually in Sections E.6.1 to E.6.5. As discussed in Section E.3.1, multiple exposure scenarios are considered in this assessment to account for the uncertainty of long-term Hanford Site land use. To simplify the presentation, the individual case discussions focus on the results for the industrial worker scenario. Results for all the receptor scenarios are provided in table format for each case; however, for comparison purposes, a single scenario is sufficient because the relationship between the receptor scenarios remains relatively consistent within each case. For example, regardless of the case or compliance point, the peak residential farmer ILCR is always approximately 35 times higher than the peak industrial worker ILCR, and the MTCA Method B peak hazard index is always approximately 2.2 times higher than the MTCA Method C peak hazard index.

E.6.1 BASE CASE, NO ACTION ALTERNATIVE (CASE 1)

Results for the base case (Case 1) are summarized in Table E.38. Results for Case 1 reveal three general trends that are also evident in the results for the other cases considered (Cases 2, 9, 10, 11). First, peak values for the cross-sections at the WMA S-SX boundary exceed the peak values for the downgradient compliance points. Second, peak values at the WMA S-SX boundary are highest for cross-sections SX-DD' or SX-FF', followed by cross-section S-CC'. Third, peak values at the last compliance point (i.e., the Columbia River shoreline) are generally three to four orders of magnitude lower than the peak values at the WMA S-SX boundary.

Peak values for Case 1 are the highest of the five cases considered. Between the WMA S-SX boundary and the Columbia River shoreline compliance location, the peak industrial worker ILCR varies from 9.98×10^{-3} to 1.33×10^{-6}. Peak ILCR values are driven by technetium-99. The peak industrial worker hazard index varies from 3.00×10^{2} to 4.22×10^{-2}. Peak hazard index values are driven by chromium. The peak dose varies from 5.94×10^{2} mrem/yr to 7.94×10^{-2} mrem/yr. Peak dose values are driven by technetium-99.

Temporal variations in ILCR for Case 1 are shown in Figure E.32 for compliance points at the WMA S-SX boundary and in Figure E.33 for compliance points between the WMA S-SX boundary and the Columbia River. Temporal variations in hazard index and dose for Case 1 are similar to those shown for ILCR. At the WMA S-SX boundary, peaks for the three cross-sections arrive within approximately the first 50 years and are all relatively sharp. Peaks at the 200 West fence, 200 Area exclusion boundary, and Columbia River shoreline compliance locations arrive after approximately 180, 350, and 550 years, respectively, and are broader than the peaks at the WMA S-SX boundary.

Figure E.32. Case 1 Industrial Worker ILCR Versus Time at WMA S-SX Boundary

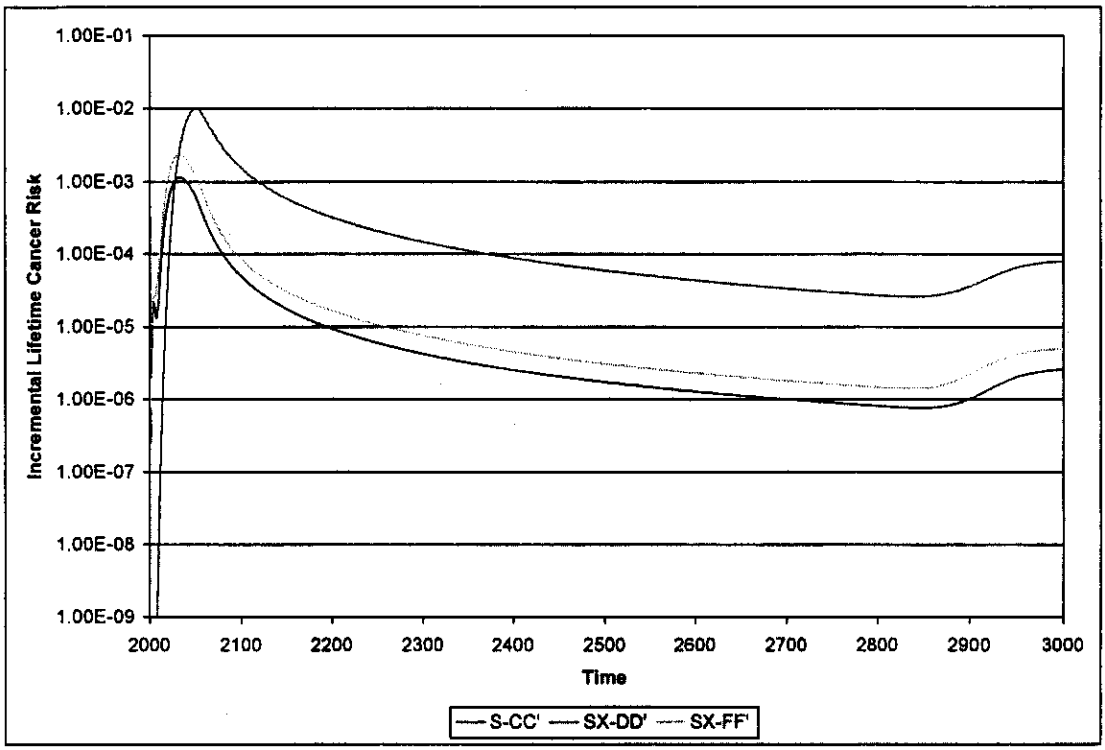


Figure E.33. Case 1 Industrial Worker ILCR Versus Time at Compliance Points Between the WMA S-SX Boundary and the Columbia River

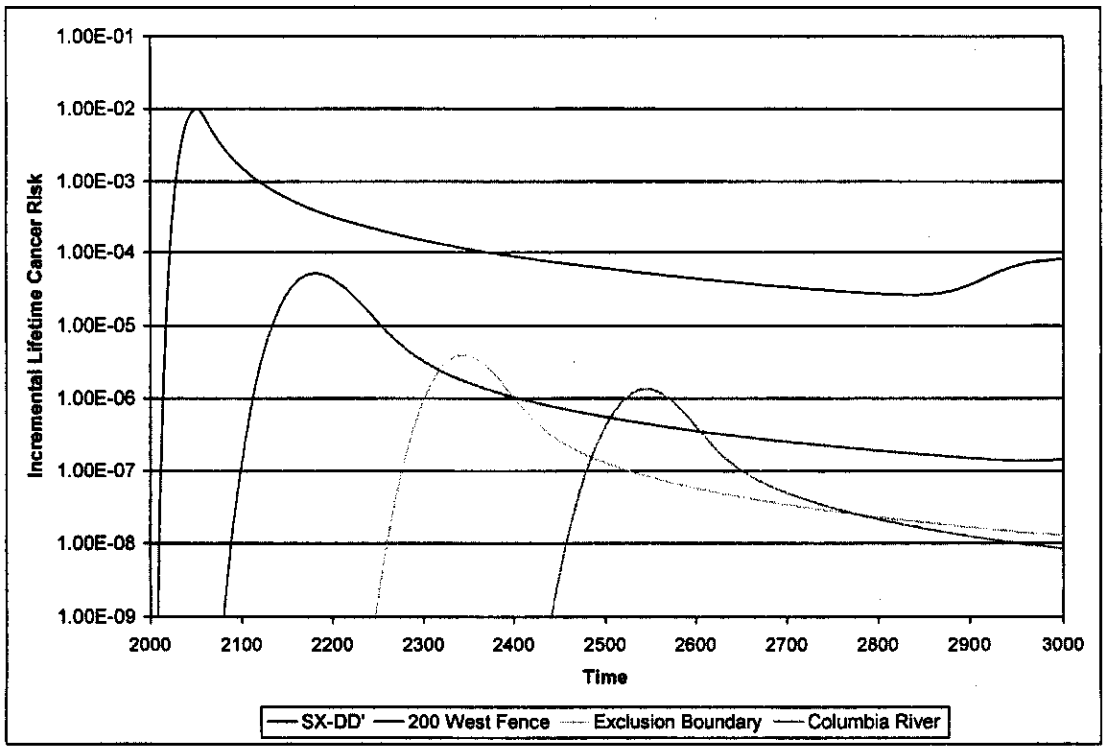


Table E.38. Peak Long-Term Human Health Impacts for Case 1

Compliance Point		Residential Farmer		Industrial Worker		Recreational Shoreline User[a]		MTCA Method B[b]		MTCA Method C[b]		Dose to Worker
		ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	mrem/yr
S-SX WMA Boundary	S - CC'	4.13E-02	5.07E+03	1.15E-03	1.16E+01	N/A	N/A	N/A	2.13E+02	N/A	9.75E+01	6.91E+01
	SX - DD'	3.57E-01	2.09E+04	9.98E-03	3.00E+02	N/A	N/A	N/A	2.77E+03	N/A	1.26E+03	5.94E+02
	SX - FF'	8.39E-02	6.09E+03	2.34E-03	1.96E+01	N/A	N/A	N/A	5.20E+02	N/A	2.38E+02	1.40E+02
200 West Fence		1.82E-03	7.70E+01	5.07E-05	1.60E+00	N/A	N/A	N/A	1.32E+01	N/A	6.02E+00	3.02E+00
200 Area Exclusion Boundary		1.41E-04	5.98E+00	3.94E-06	1.24E-01	N/A	N/A	N/A	1.02E+00	N/A	4.67E-01	2.35E-01
Columbia River Shoreline		4.77E-05	2.02E+00	1.33E-06	4.22E-02	2.21E-07	4.52E-03	N/A	3.48E-01	N/A	1.59E-01	7.94E-02

[a]Exposures defined to occur only within 400 m (1,300 ft) of the Columbia River shoreline.
[b]Cancer risks not shown because MTCA addresses only nonradioactive contaminants and no nonradioactive carcinogenic chemicals were identified as contaminants of concern for WMA S-SX.

HI = hazard index.
ILCR = incremental lifetime cancer risk.
MTCA = Model Toxics Control Act.
N/A = not applicable.

E.6.2 BARRIER ALTERNATIVE AND NO WATER-LINE LEAKS CASE (CASE 2)

Results for Case 2, barrier alternative and no water-line leaks, are summarized in Table E.39. Results for Case 2 show the same general trends regarding the compliance points as discussed above for Case 1. Peak values for Case 2 are generally a factor of 2 to 10 lower than the corresponding values for Case 1. Between the WMA S-SX boundary and the Columbia River shoreline, the peak industrial worker ILCR varies from 1.65×10^{-3} to 5.30×10^{-7}. Peak ILCR values are driven by technetium-99. The peak industrial worker hazard index varies from 2.99×10^{1} to 8.79×10^{-3}. Peak hazard index values are driven by chromium and nitrate. The peak dose ranges from 9.85×10^{1} mrem/yr to 3.16×10^{-2} mrem/yr. Peak dose values are driven by technetium-99.

Temporal variations in ILCR for Case 2 are shown in Figure E.34 for compliance points at the WMA S-SX boundary and in Figure E.35 for compliance points between the WMA S-SX boundary and the Columbia River. Temporal variations in hazard index and dose for Case 2 are similar to those shown for ILCR. At the WMA S-SX boundary, peak arrival times for the three cross-sections are similar to Case 1 but the peaks are broader in shape. All three peaks arrive within approximately the first 60 years. Peaks at the 200 West fence, 200 Area exclusion boundary, and Columbia River shoreline compliance locations are also similar to and slightly broader than Case 1 and arrive after approximately 180, 350, and 550 years, respectively.

Figure E.34. Case 2 Industrial Worker ILCR Versus Time at WMA S-SX Boundary

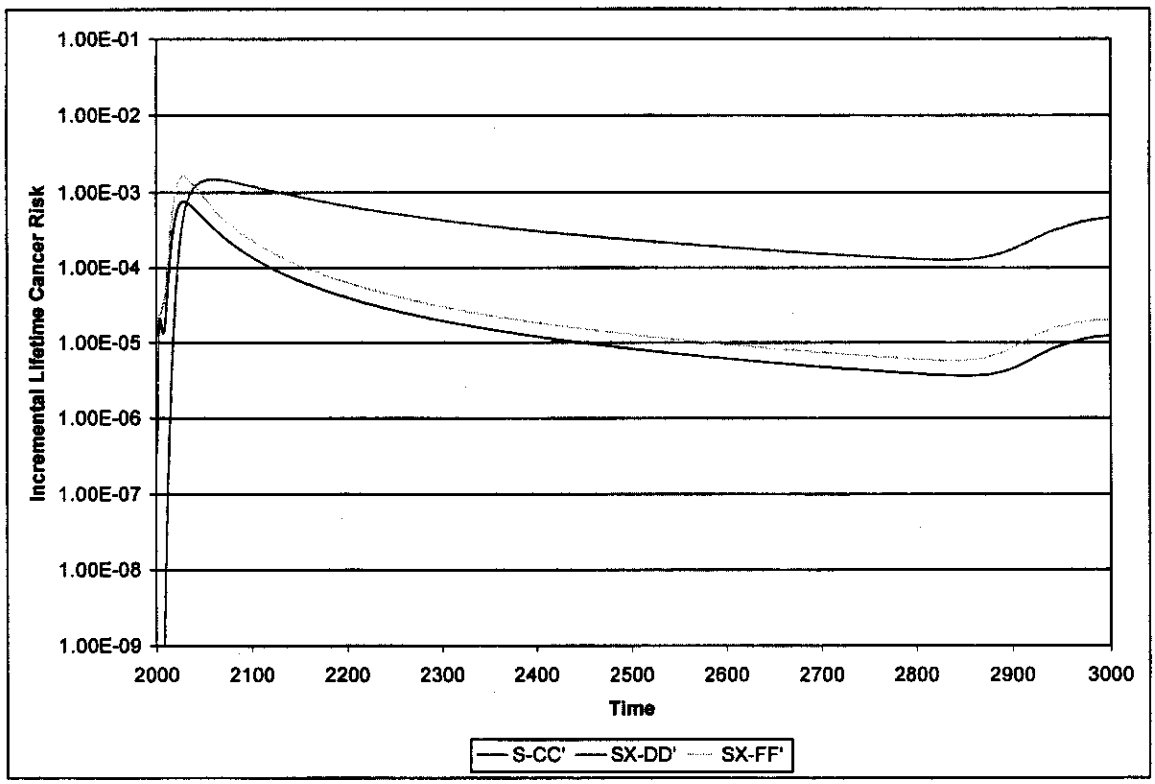


Figure E.35. Case 2 Industrial Worker ILCR Versus Time at Compliance Points Between the WMA S-SX Boundary and the Columbia River

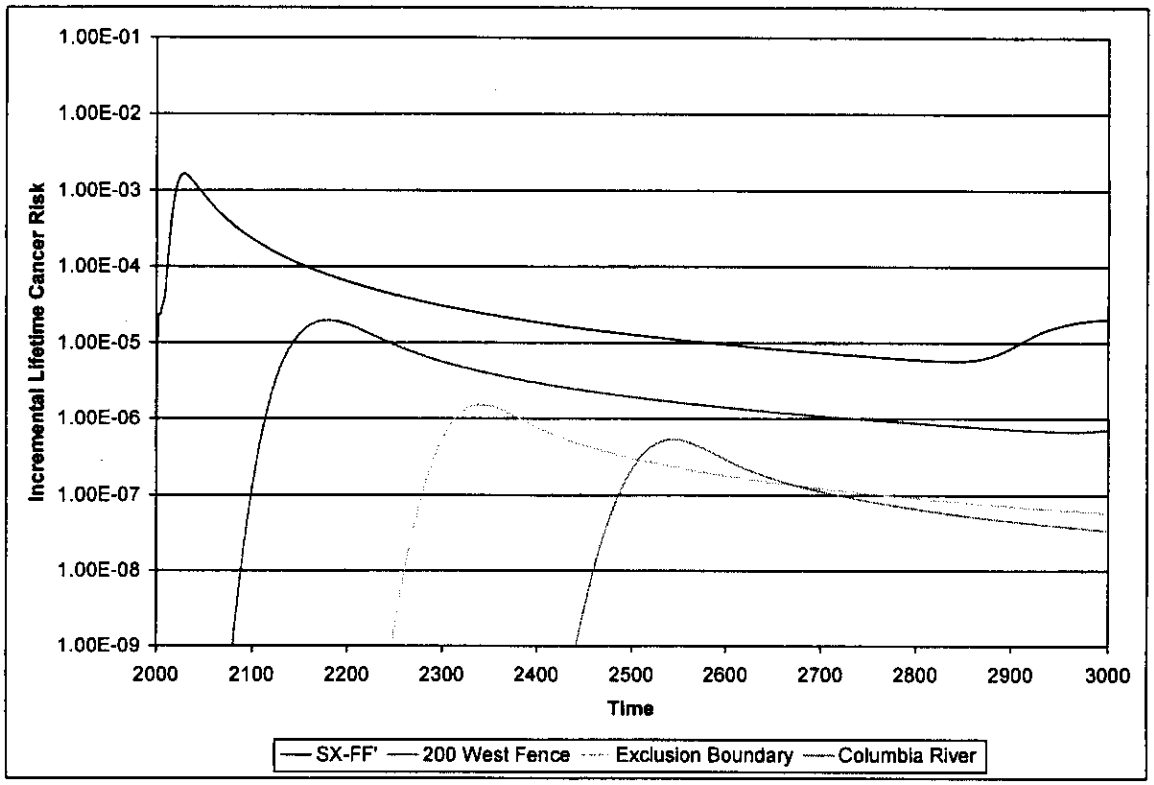


Table E.39. Peak Long-Term Human Health Impacts for Case 2

Compliance Point		Residential Farmer		Industrial Worker		Recreational Shoreline User[a]		MTCA Method B[b]		MTCA Method C[b]		Dose to Worker
		ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	mrem/yr
S-SX WMA Boundary	S - CC'	2.76E-02	3.43E+03	7.68E-04	5.35E+00	N/A	N/A	N/A	1.36E+02	N/A	6.20E+01	4.61E+01
	SX - DD'	5.32E-02	3.35E+03	1.49E-03	2.99E+01	N/A	N/A	N/A	3.28E+02	N/A	1.57E+02	8.86E+01
	SX - FF'	5.91E-02	4.11E+03	1.65E-03	9.77E+00	N/A	N/A	N/A	3.39E+02	N/A	1.55E+02	9.85E+01
200 West Fence		7.08E-04	3.36E+01	1.98E-05	3.25E-01	N/A	N/A	N/A	3.38E+00	N/A	1.55E+00	1.18E+00
200 Area Exclusion Boundary		5.46E-05	2.60E+00	1.53E-06	2.45E-02	N/A	N/A	N/A	2.58E-01	N/A	1.18E-01	9.10E-02
Columbia River Shoreline		1.90E-05	9.00E-01	5.30E-07	8.79E-03	8.81E-08	9.60E-04	N/A	9.14E-02	N/A	4.18E-02	3.16E-02

[a]Exposures defined to occur only within 400 m (1,300 ft) of the Columbia River shoreline.
[b]Cancer risks not shown because MTCA addresses only nonradioactive contaminants and no nonradioactive carcinogenic chemicals were identified as contaminants of concern for WMA S-SX.

HI = hazard index.
ILCR = incremental lifetime cancer risk.
MTCA = Model Toxics Control Act.
N/A = not applicable.

E.6.3 BASE CASE WITH 50 MM/YR METEORIC RECHARGE (CASE 9)

Results for Case 9, base case with 50 mm/yr meteoric recharge, are summarized in Table E.40. Results for Case 9 show the same general trends regarding the compliance points as discussed above for Case 1. Peak values for Case 9 are generally a factor of 2 to 4 lower than the corresponding values for Case 1. Between the WMA S-SX boundary and the Columbia River shoreline, the peak industrial worker ILCR varies from 3.03×10^{-3} to 6.92×10^{-7}. Peak ILCR values are driven by technetium-99. The peak industrial worker hazard index varies from 6.73×10^{1} to 1.52×10^{-2}. Peak hazard index values are driven by chromium and nitrate. The peak dose varies from 1.80×10^{2} mrem/yr to 4.13×10^{-2} mrem/yr. Peak dose values are driven by technetium-99.

Temporal variations in ILCR for Case 9 are shown in Figure E.36 for compliance points at the WMA S-SX boundary and in Figure E.37 for compliance points between the WMA S-SX boundary and the Columbia River. Temporal variations in hazard index and dose for Case 9 are similar to those shown for ILCR. Overall, the temporal variations for Case 9 resemble those for Case 2. At the WMA S-SX boundary, peaks for the three cross-sections have slightly delayed arrival times and broader shapes compared to Case 1. All three peaks arrive within the first 75 years. Peaks at the 200 West fence, 200 Area exclusion boundary, and Columbia River shoreline compliance locations are also slightly delayed and broadened compared to Case 1.

Figure E.36. Case 9 Industrial Worker ILCR Versus Time at WMA S-SX Boundary

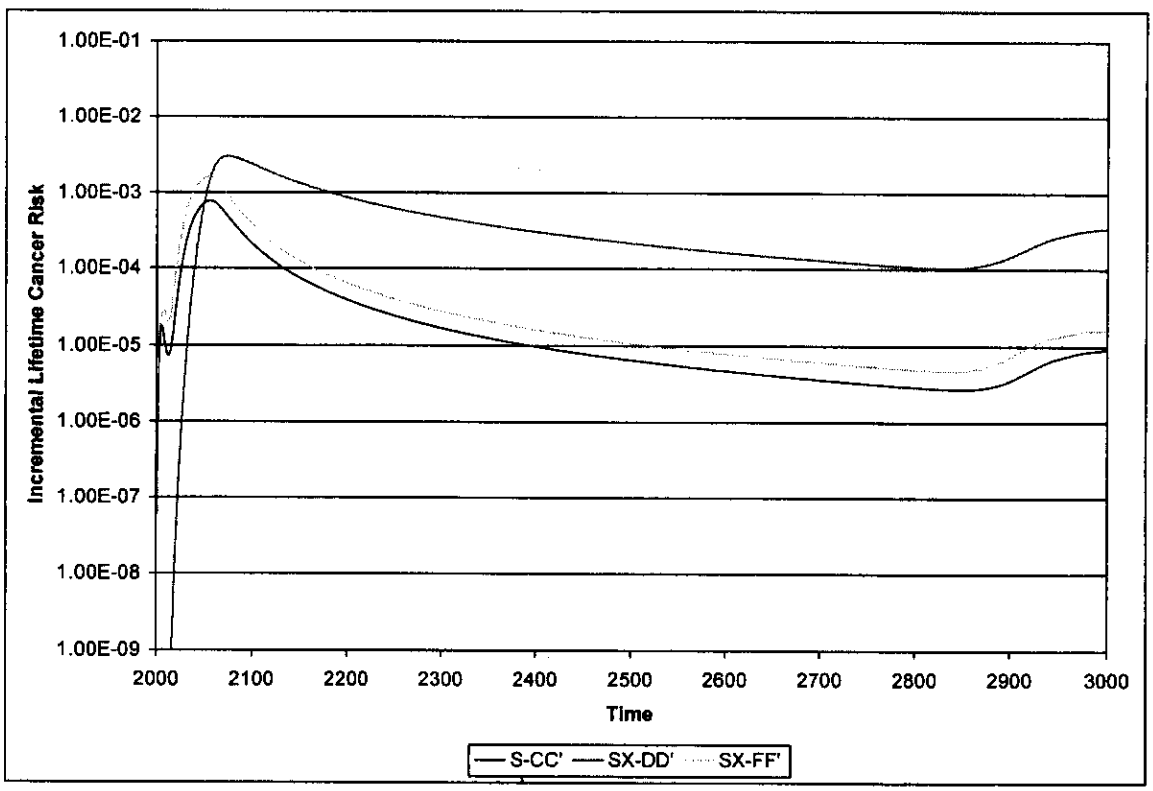


Figure E.37. Case 9 Industrial Worker ILCR Versus Time at Compliance Points Between the WMA S-SX Boundary and the Columbia River

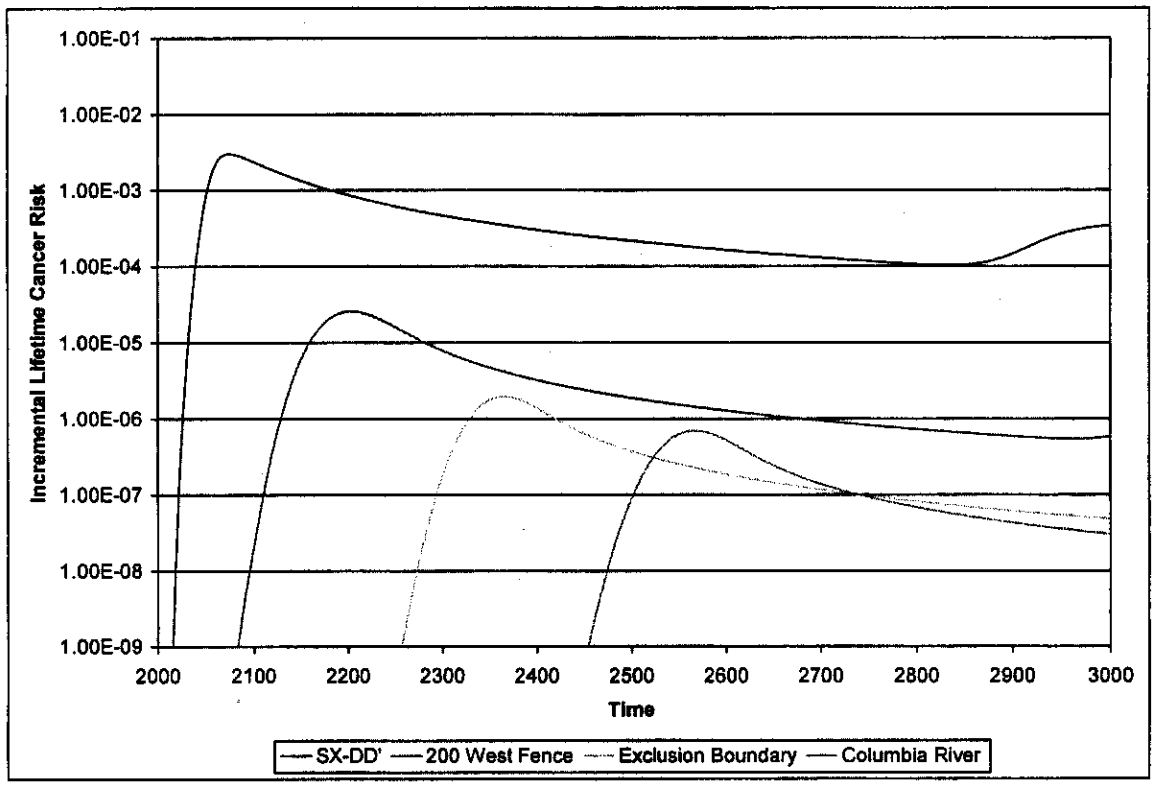


Table E.40. Peak Long-Term Human Health Impacts for Case 9

Compliance Point		Residential Farmer		Industrial Worker		Recreational Shoreline User[a]		MTCA Method B[b]		MTCA Method C[b]		Dose to Worker
		ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	mrem/yr
S-SX WMA Boundary	S - CC'	2.76E-02	3.40E+03	7.70E-04	6.29E+00	N/A	N/A	N/A	1.40E+02	N/A	6.39E+01	4.63E+01
	SX - DD'	1.08E-01	6.45E+03	3.03E-03	6.73E+01	N/A	N/A	N/A	6.95E+02	N/A	3.18E+02	1.80E+02
	SX - FF'	5.81E-02	4.23E+03	1.62E-03	1.19E+01	N/A	N/A	N/A	3.58E+02	N/A	1.64E+02	9.69E+01
200 West Fence		9.27E-04	4.20E+01	2.59E-05	5.63E-01	N/A	N/A	N/A	5.21E+00	N/A	2.38E+00	1.54E+00
200 Area Exclusion Boundary		7.10E-05	3.22E+00	1.99E-06	4.29E-02	N/A	N/A	N/A	3.97E-01	N/A	1.81E-01	1.18E-01
Columbia River Shoreline		2.48E-05	1.12E+00	6.92E-07	1.52E-02	1.15E-07	1.64E-03	N/A	1.40E-01	N/A	6.40E-02	4.13E-02

[a]Exposures defined to occur only within 400 m (1,300 ft) of the Columbia River shoreline.
[b]Cancer risks not shown because MTCA addresses only nonradioactive contaminants and no nonradioactive carcinogenic chemicals were identified as contaminants of concern for WMA S-SX.

HI = hazard index.
ILCR = incremental lifetime cancer risk.
MTCA - Model Toxics Control Act.
N/A = not applicable.

E.6.4 BASE CASE WITH 30 MM/YR METEORIC RECHARGE (CASE 10)

Results for Case 10, base case with 30 mm/yr meteoric recharge, are summarized in Table E.41. Results for Case 10 show the same general trends regarding the compliance points as discussed above for Case 1. Peak values for Case 10 are generally a factor of 2 to 15 lower than the corresponding values for Case 1. Between the WMA S-SX boundary and the Columbia River shoreline, the peak industrial worker ILCR varies from 1.01×10^{-3} to 3.67×10^{-7}. Peak ILCR values are driven by technetium-99. The peak industrial worker hazard index varies from 2.07×10^{1} to 5.69×10^{-3}. Peak hazard index values are driven by chromium and nitrate. The peak dose ranges from 6.01×10^{1} mrem/yr to 2.19×10^{-2} mrem/yr. Peak dose values are driven by technetium-99.

Temporal variations in ILCR for Case 10 are shown in Figure E.38 for compliance points at the WMA S-SX boundary and in Figure E.39 for compliance points between the WMA S-SX boundary and the Columbia River. Temporal variations in hazard index and dose for Case 10 are similar to those shown for ILCR. At the WMA S-SX boundary, peaks for the three cross-sections are further delayed in arrival times and have even broader shapes compared to Case 9. The three peaks arrive within approximately 125 years. The curves for the three cross-sections begin to rise again after approximately 900 years and are still rising at the end of the 1,000-year analysis period. Peaks at the 200 West fence, 200 Area exclusion boundary, and Columbia River shoreline compliance locations are also further delayed and broadened compared to Case 9.

Figure E.38. Case 10 Industrial Worker ILCR Versus Time at WMA S-SX Boundary

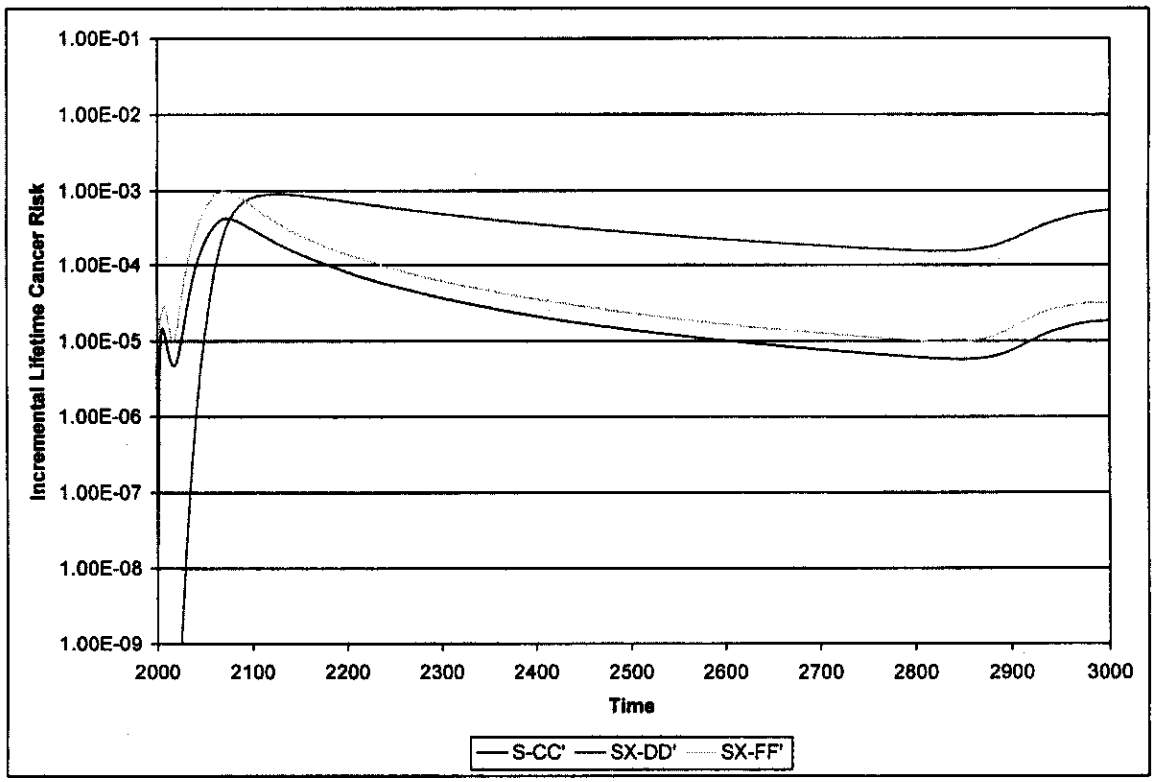


Figure E.39. Case 10 Industrial Worker ILCR Versus Time at Compliance Points Between the WMA S-SX Boundary and the Columbia River

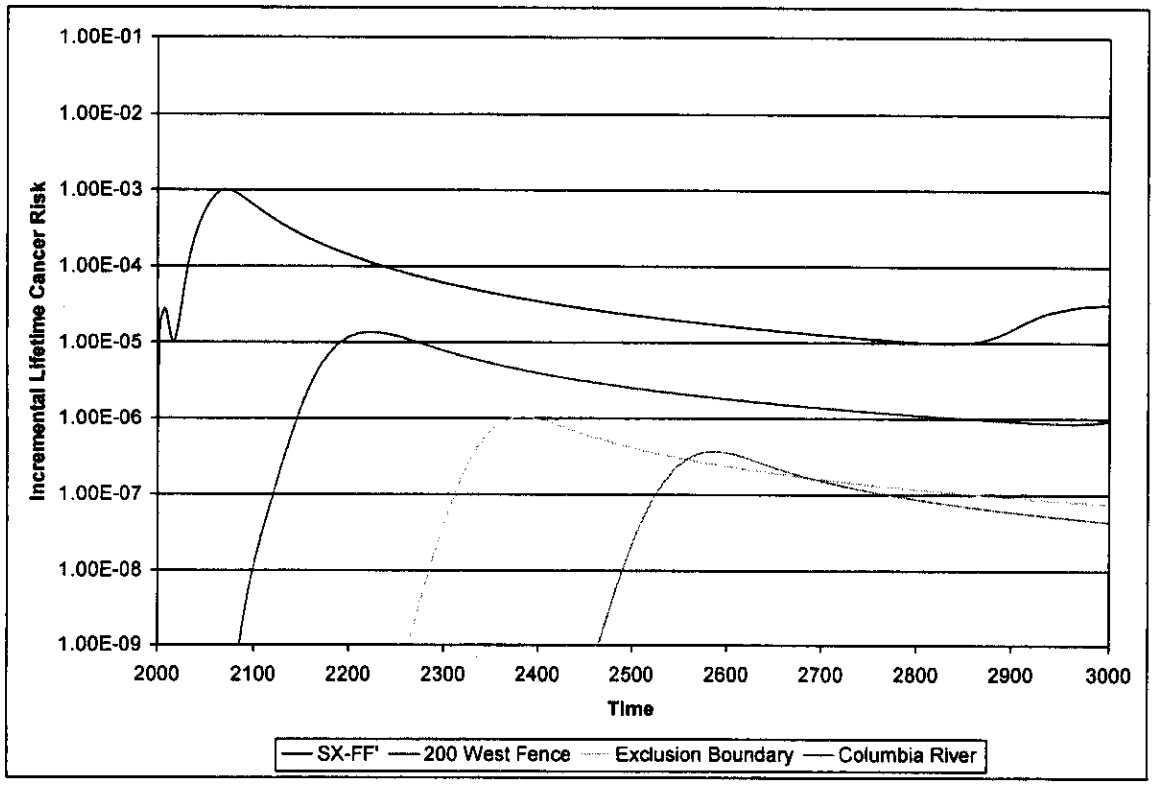


Table E.41. Peak Long-Term Human Health Impacts for Case 10

Compliance Point		Residential Farmer		Industrial Worker		Recreational Shoreline User[a]		MTCA Method B[b]		MTCA Method C[b]		Dose to Worker
		ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	mrem/yr
S-SX WMA Boundary	S - CC'	1.56E-02	1.95E+03	4.36E-04	3.08E+00	N/A	N/A	N/A	7.75E+01	N/A	3.54E+01	2.61E+01
	SX - DD'	3.23E-02	1.98E+03	9.02E-04	2.07E+01	N/A	N/A	N/A	1.98E+02	N/A	9.03E+01	5.37E+01
	SX - FF'	3.61E-02	2.60E+03	1.01E-03	6.30E+00	N/A	N/A	N/A	2.15E+02	N/A	9.82E+01	6.01E+01
200 West Fence		4.88E-04	2.36E+01	1.36E-05	2.11E-01	N/A	N/A	N/A	2.23E+00	N/A	1.02E+00	8.14E-01
200 Area Exclusion Boundary		3.70E-05	1.79E+00	1.03E-06	1.57E-02	N/A	N/A	N/A	1.67E-01	N/A	7.63E-02	6.17E-02
Columbia River Shoreline		1.31E-05	6.34E-01	3.67E-07	5.69E-03	6.10E-08	6.22E-04	N/A	6.02E-02	N/A	2.75E-02	2.19E-02

[a]Exposures defined to occur only within 400 m (1,300 ft) of the Columbia River shoreline.
[b]Cancer risks not shown because MTCA addresses only nonradioactive contaminants and no nonradioactive carcinogenic chemicals were identified as contaminants of concern for WMA S-SX.

HI = hazard index.
ILCR = incremental lifetime cancer risk.
MTCA - Model Toxics Control Act.
N/A = not applicable.

E.6.5 BASE CASE WITH 10 MM/YR METEORIC RECHARGE (CASE 11)

Results for Case 11, base case with 10 mm/yr meteoric recharge, are summarized in Table E.42. Results for Case 11 show the same general trends regarding the compliance points as discussed above for Case 1. Peak values for Case 11 are generally a factor of 15 to 50 lower than the corresponding values for Case 1. Between the WMA S-SX boundary and the Columbia River shoreline, the peak industrial worker ILCR varies from 5.94×10^{-4} to 8.59×10^{-8}. Peak ILCR values are driven by technetium-99. The peak industrial worker hazard index varies from 1.25×10^{1} to 7.54×10^{-4}. Peak hazard index values are driven by chromium. The peak dose varies from 3.26×10^{1} mrem/yr to 5.12×10^{-3} mrem/yr. Peak dose values are driven by technetium-99.

Temporal variations in ILCR for Case 11 are shown in Figure E.40 for compliance points at the WMA S-SX boundary and in Figure E.41 for compliance points between the WMA S-SX boundary and the Columbia River. Temporal variations in hazard index and dose for Case 11 are similar to those shown for ILCR. At the WMA S-SX boundary, peaks for the three cross-sections are even further delayed in arrival times and have even broader shapes compared to Case 10. The secondary elevation in ILCR values observed for Case 10 at the end of the 1,000-year analysis period is also observed for Case 11 but is more pronounced. For cross-section SX-DD', the late ILCR peak actually exceeds the earlier peak. Peaks at the 200 West Fence, 200 Area exclusion boundary, and Columbia River shoreline compliance locations are also even further delayed and broadened compared to Case 10 and arrive after approximately 300, 480, and 680 years, respectively.

Figure E.40. Case 11 Industrial Worker ILCR Versus Time at WMA S-SX Boundary

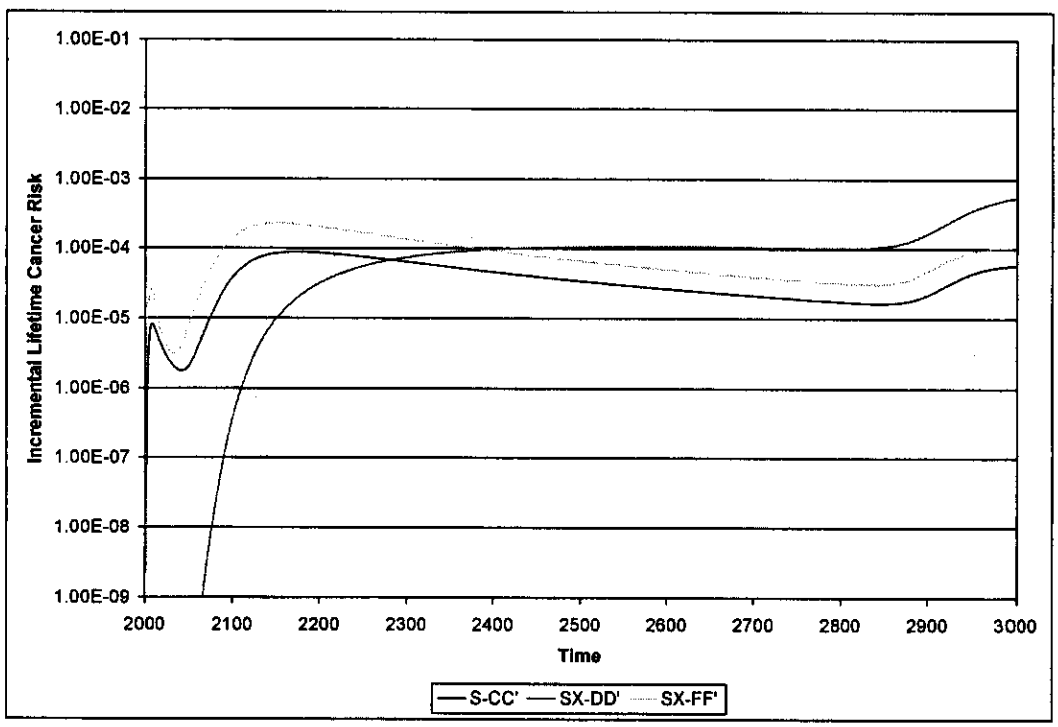


Figure E.41. Case 11 Industrial Worker ILCR Versus Time at Compliance Points Between the WMA S-SX Boundary and the Columbia River

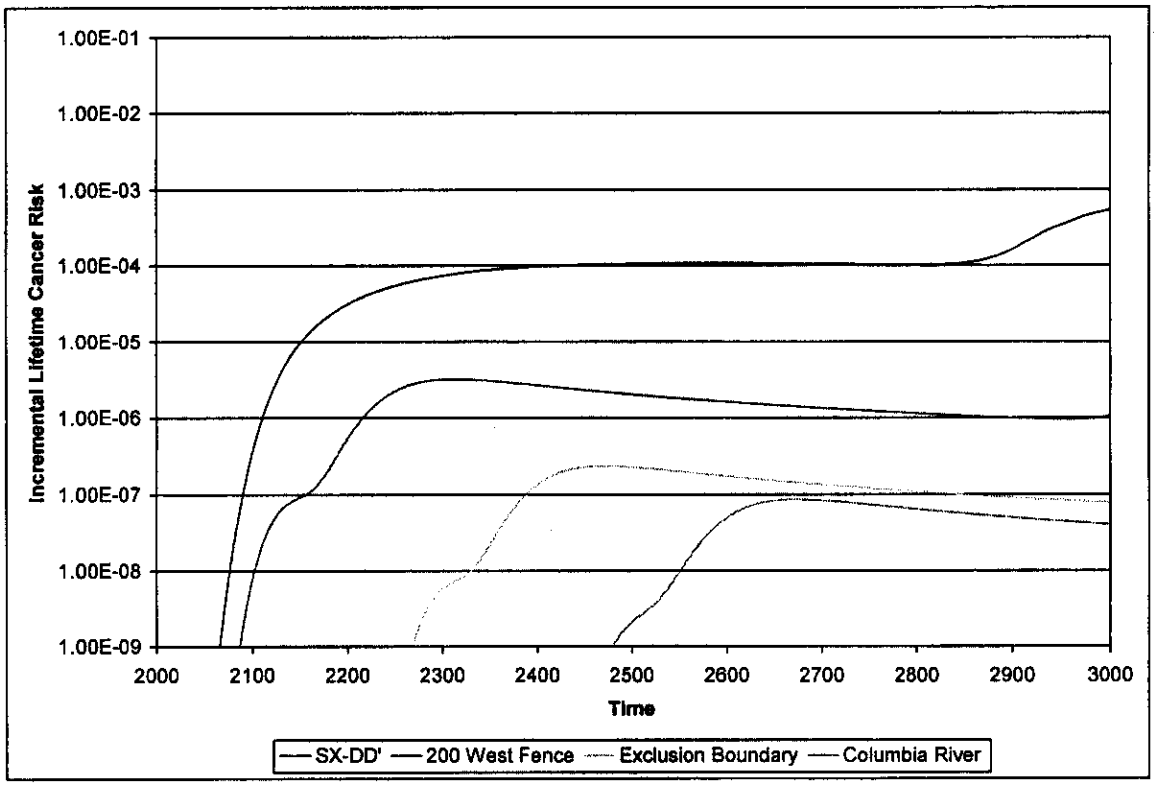


Table E.42. Peak Long-Term Human Health Impacts for Case 11

Compliance Point		Residential Farmer		Industrial Worker		Recreational Shoreline User[a]		MTCA Method B[b]		MTCA Method C[b]		Dose to Worker
		ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	ILCR	HI	mrem/yr
S-SX WMA Boundary	S - CC'	3.16E-03	4.08E+02	8.82E-05	7.67E-01	N/A	N/A	N/A	1.59E+01	N/A	7.25E+00	5.29E+00
	SX - DD'	1.96E-02	1.12E+03	5.49E-04	1.25E+01	N/A	N/A	N/A	1.27E+02	N/A	5.82E+01	3.26E+01
	SX - FF'	8.14E-03	5.94E+02	2.27E-04	1.43E+00	N/A	N/A	N/A	4.84E+01	N/A	2.21E+01	1.36E+01
200 West Fence		1.14E-04	5.70E+00	3.19E-06	2.81E-02	N/A	N/A	N/A	3.85E-01	N/A	1.76E-01	1.90E-01
200 Area Exclusion Boundary		8.40E-06	4.19E-01	2.35E-07	2.04E-03	N/A	N/A	N/A	2.81E-02	N/A	1.28E-02	1.40E-02
Columbia River Shoreline		3.07E-06	1.54E-01	8.59E-08	7.54E-04	1.43E-08	8.38E-05	N/A	1.03E-02	N/A	4.73E-03	5.12E-03

[a]Exposures defined to occur only within 400 m (1,300 ft) of the Columbia River shoreline.
[b]Cancer risks not shown because MTCA addresses only nonradioactive contaminants and no nonradioactive carcinogenic chemicals were identified as contaminants of concern for WMA S-SX.

HI = hazard index.
ILCR = incremental lifetime cancer risk.
MTCA = Model Toxics Control Act.
N/A = not applicable.

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ATTACHMENT E1

VADOSE ZONE INVENTORY ESTIMATES

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TABLES

E1.1. Vadose Zone Inventory Estimates for Cs-137 for Individual Tanks E1-1
E1.2. Vadose Zone Inventory Estimates for Tc-99 for Individual Tanks E1-2
E1.3. Vadose Zone Inventory Estimates for NO_3 for Individual Tanks E1-5
E1.4. Vadose Zone Inventory Estimates for Cr for Individual Tanks E1-8

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Table E1.1. Vadose Zone Inventory Estimates for Cs-137 for Individual Tanks

SX-107			SX-108			SX-109		
Depth (ft) bgs	1/1/00 Cs-137(Ci)	1/1/00 Cs-137 (pCi/g)	Depth (ft) bgs	1/1/00 Cs-137(Ci)	1/1/00 Cs-137 (pCi/g)	Depth (ft) bgs	1/1/00 Cs-137(Ci)	1/1/00 Cs-137 (pCi/g)
47.6-57.4	2.13E-02	3.38E+02	47.6-57.4	1.54E-01	1.76E+03	47.6-57.4	5.25E-04	2.92E+02
57.4-67.2	1.36E+04	2.63E+07	57.4-67.2	2.32E+04	1.65E+07	57.4-67.2	3.39E+02	4.65E+05
67.2-77.1	1.24E+03	3.31E+06	67.2-77.1	1.29E+04	1.34E+07	67.2-77.1	1.03E+03	6.27E+05
77.1-86.9	1.54E-01	1.60E+03	77.1-86.9	7.36E+01	2.53E+05	77.1-86.9	9.32E+02	1.14E+06
			86.9-96.8	9.81E-01	8.42E+03	86.9-96.8	2.06E+02	5.97E+05
			96.8-106.6	1.91E-01	1.26E+03	96.8-106.6	1.75E+01	2.61E+04
			106.6-116.4	9.05E-02	8.78E+02	106.6-116.4	4.15E+00	1.11E+04
			116.4-126.3	3.53E-02	2.88E+02	116.4-126.3	1.01E+00	2.13E+03
			126.3-136.1	6.28E-03	1.94E+02	126.3-136.1	2.73E-01	1.34E+03
SX-113			SX-115			S-104		
Depth (ft) bgs	1/1/00 Cs-137(Ci)	1/1/00 Cs-137 (pCi/g)	Depth (ft) bgs	1/1/00 Cs-137(Cl)	1/1/00 Cs-137 (pCi/g)	Depth (ft) bgs	1/1/00 Cs-137(Ci)	1/1/00 Cs-137 (pCi/g)
56-64	6.38E+03	1.40E+07	56-64	1.63E+04	1.07E+07	40-52	9.91E+03	1.36E+07

Table E1.2. Vadose Zone Inventory Estimates for Tc-99 for Individual Tanks (3 Sheets)

SX-107			SX-108			SX-109		
Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)
25-26	1.53E-01	2.07E-05	25-26	1.53E-01	4.98E-05	25-26	1.53E-01	3.22E-06
44-45	9.63E-01	1.30E-04	44-45	9.63E-01	3.13E-04	44-45	9.63E-01	2.03E-05
56-57	5.06E-01	6.84E-05	56-57	5.06E-01	1.65E-04	56-57	5.06E-01	1.07E-05
61-62	6.97E-01	9.43E-05	61-62	6.97E-01	2.27E-04	61-62	6.97E-01	1.47E-05
65-66	5.32E+00	7.19E-04	65-66	5.32E+00	1.73E-03	65-66	5.32E+00	1.12E-04
69-70	5.52E+00	7.46E-04	69-70	5.52E+00	1.80E-03	69-70	5.52E+00	1.16E-04
74-75	7.72E+00	1.04E-03	74-75	7.72E+00	2.51E-03	74-75	7.72E+00	1.63E-04
79-80	1.82E+01	2.46E-03	79-80	1.82E+01	5.92E-03	79-80	1.82E+01	3.84E-04
82-83	3.93E+02	5.31E-02	82-83	3.93E+02	1.28E-01	82-83	3.93E+02	8.28E-03
90	2.75E+03	3.72E-01	90	2.75E+03	8.95E-01	90	2.75E+03	5.80E-02
95-96	7.08E+03	9.57E-01	95-96	7.08E+03	2.30E+00	95-96	7.08E+03	1.49E-01
102-103	6.14E+03	8.30E-01	102-103	6.14E+03	2.00E+00	102-103	6.14E+03	1.29E-01
108-109	1.19E+04	1.61E+00	108-109	1.19E+04	3.87E+00	108-109	1.19E+04	2.51E-01
112	8.56E+03	1.16E+00	112	8.56E+03	2.78E+00	112	8.56E+03	1.80E-01
127.4	3.34E+02	4.52E-02	127.4	3.34E+02	1.09E-01	127.4	3.34E+02	7.04E-03
SX-113			**SX-115**			**S-104**		
Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)
33	0.85	4.18E-04	33	0.85	9.23E-04	33	0.85	6.47E-04
56.25	0.85	4.18E-04	56.25	0.85	9.22E-04	56.25	0.85	6.47E-04
57.5	0.85	4.18E-04	57.5	0.85	9.23E-04	57.5	0.85	6.47E-04
61.25	0.85	4.16E-04	61.25	0.85	9.19E-04	61.25	0.85	6.45E-04
62.75	0.85	4.17E-04	62.75	0.85	9.22E-04	62.75	0.85	6.46E-04
63.25	0.84	4.16E-04	63.25	0.84	9.19E-04	63.25	0.84	6.44E-04
63.75	0.65	3.22E-04	63.75	0.65	7.12E-04	63.75	0.65	4.99E-04
64.75	0.84	4.16E-04	64.75	0.84	9.18E-04	64.75	0.84	6.44E-04
68	0.85	4.17E-04	68	0.85	9.20E-04	68	0.85	6.45E-04
70	0.85	4.18E-04	70	0.85	9.23E-04	70	0.85	6.47E-04
71	0.85	4.18E-04	71	0.85	9.23E-04	71	0.85	6.47E-04
73.25	12.89	6.35E-03	73.25	12.89	1.40E-02	73.25	12.89	9.84E-03
73.75	41.75	2.06E-02	73.75	41.75	4.54E-02	73.75	41.75	3.19E-02
74.25	47.07	2.32E-02	74.25	47.07	5.12E-02	74.25	47.07	3.59E-02
75.25	33.07	1.63E-02	75.25	33.07	3.60E-02	75.25	33.07	2.52E-02
79.25	29.44	1.45E-02	79.25	29.44	3.20E-02	79.25	29.44	2.25E-02
79.75	25.43	1.25E-02	79.75	25.43	2.77E-02	79.75	25.43	1.94E-02

Table E1.2. Vadose Zone Inventory Estimates for Tc-99 for Individual Tanks (3 Sheets)

SX-113			SX-115			S-104		
Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)
80.25	32.11	1.58E-02	80.25	32.11	3.49E-02	80.25	32.11	2.45E-02
87	7.19	3.54E-03	87	7.19	7.83E-03	87	7.19	5.49E-03
88.4	47.61	2.35E-02	88.4	47.61	5.18E-02	88.4	47.61	3.63E-02
95	30.57	1.51E-02	95	30.57	3.33E-02	95	30.57	2.33E-02
99	7.97	3.93E-03	99	7.97	8.67E-03	99	7.97	6.08E-03
100	34.63	1.71E-02	100	34.63	3.77E-02	100	34.63	2.64E-02
103.25	12.89	6.35E-03	103.25	12.89	1.40E-02	103.25	12.89	9.83E-03
105.25	12.73	6.28E-03	105.25	12.73	1.39E-02	105.25	12.73	9.71E-03
107	36.31	1.79E-02	107	36.31	3.95E-02	107	36.31	2.77E-02
116	36.93	1.82E-02	116	36.93	4.02E-02	116	36.93	2.82E-02
123.8	82.59	4.07E-02	123.8	82.59	8.99E-02	123.8	82.59	6.30E-02
124.35	82.59	4.07E-02	124.35	82.59	8.99E-02	124.35	82.59	6.30E-02
125.35	222.01	1.09E-01	125.35	222.01	2.42E-01	125.35	222.01	1.69E-01
126.35	362.77	1.79E-01	126.35	362.77	3.95E-01	126.35	362.77	2.77E-01
129.45	542.80	2.68E-01	129.45	542.80	5.91E-01	129.45	542.80	4.14E-01
132.45	390.39	1.92E-01	132.45	390.39	4.25E-01	132.45	390.39	2.98E-01
134.45	99.60	4.91E-02	134.45	99.60	1.08E-01	134.45	99.60	7.60E-02
136	364.64	1.80E-01	136	364.64	3.97E-01	136	364.64	2.78E-01
138.2	346.77	1.71E-01	138.2	346.77	3.77E-01	138.2	346.77	2.65E-01
140.65	328.05	1.62E-01	140.65	328.05	3.57E-01	140.65	328.05	2.50E-01
141.65	252.62	1.24E-01	141.65	252.62	2.75E-01	141.65	252.62	1.93E-01
142.75	281.68	1.39E-01	142.75	281.68	3.07E-01	142.75	281.68	2.15E-01
144.2	216.55	1.07E-01	144.2	216.55	2.36E-01	144.2	216.55	1.65E-01
145.65	185.12	9.12E-02	145.65	185.12	2.01E-01	145.65	185.12	1.41E-01
146.65	286.49	1.41E-01	146.65	286.49	3.12E-01	146.65	286.49	2.19E-01
147.55	48.46	2.39E-02	147.55	48.46	5.27E-02	147.55	48.46	3.70E-02
148.55	190.95	9.41E-02	148.55	190.95	2.08E-01	148.55	190.95	1.46E-01
149.55	186.28	9.18E-02	149.55	186.28	2.03E-01	149.55	186.28	1.42E-01
152.2	56.32	2.78E-02	152.2	56.32	6.13E-02	152.2	56.32	4.30E-02
153.15	20.78	1.02E-02	153.15	20.78	2.26E-02	153.15	20.78	1.59E-02
155.15	3.42	1.68E-03	155.15	3.42	3.72E-03	155.15	3.42	2.61E-03
156.1	30.93	1.52E-02	156.1	30.93	3.37E-02	156.1	30.93	2.36E-02
156.55	10.58	5.22E-03	156.55	10.58	1.15E-02	156.55	10.58	8.07E-03
157.75	1.14	5.60E-04	157.75	1.14	1.24E-03	157.75	1.14	8.67E-04
158.65	2.68	1.32E-03	158.65	2.68	2.92E-03	158.65	2.68	2.05E-03

Table E1.2. Vadose Zone Inventory Estimates for Tc-99 for Individual Tanks (3 Sheets)

SX-113			SX-115			S-104		
Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)	Depth (ft) bgs	Tc-99 (pCi/g soil)	Tc-99 (Ci)
159.75	2.58	1.27E-03	159.75	2.58	2.81E-03	159.75	2.58	1.97E-03
161	1.63	8.03E-04	161	1.63	1.77E-03	161	1.63	1.24E-03
162	2.74	1.35E-03	162	2.74	2.98E-03	162	2.74	2.09E-03
166	1.59	7.82E-04	166	1.59	1.73E-03	166	1.59	1.21E-03
167	0.92	4.52E-04	167	0.92	9.97E-04	167	0.92	6.99E-04
175	0.56	2.76E-04	175	0.56	6.09E-04	175	0.56	4.27E-04
185	0.27	1.34E-04	185	0.27	2.97E-04	185	0.27	2.08E-04
184.8	0.40	1.99E-04	184.8	0.40	4.39E-04	184.8	0.40	3.08E-04
186	0.19	9.20E-05	186	0.19	2.03E-04	186	0.19	1.42E-04
190	0.29	1.42E-04	190	0.29	3.13E-04	190	0.29	2.20E-04
194.55	0.33	1.60E-04	194.55	0.33	3.54E-04	194.55	0.33	2.48E-04
204.45	3.14	1.55E-03	204.45	3.14	3.42E-03	204.45	3.14	2.40E-03
205.1	4.26	2.10E-03	205.1	4.26	4.64E-03	205.1	4.26	3.25E-03

Table E1.3. Vadose Zone Inventory Estimates for NO_3 for Individual Tanks (3 Sheets)

SX-107			SX-108			SX-109		
Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)
25-26	1.30E+01	5.23E-01	25-26	1.30E+01	1.25E+00	25-26	1.30E+01	8.13E-02
44-45	1.30E+01	5.23E-01	44-45	1.30E+01	1.25E+00	44-45	1.30E+01	8.13E-02
56-57	1.30E+01	5.23E-01	56-57	1.30E+01	1.25E+00	56-57	1.30E+01	8.13E-02
61-62	1.30E+01	5.23E-01	61-62	1.30E+01	1.25E+00	61-62	1.30E+01	8.13E-02
65-66	2.53E+01	1.02E+00	65-66	2.53E+01	2.44E+00	65-66	2.53E+01	1.58E-01
69-70	3.30E+01	1.33E+00	69-70	3.30E+01	3.18E+00	69-70	3.30E+01	2.06E-01
74-75	4.40E+01	1.77E+00	74-75	4.40E+01	4.23E+00	74-75	4.40E+01	2.75E-01
79-80	3.71E+02	1.49E+01	79-80	3.71E+02	3.57E+01	79-80	3.71E+02	2.32E+00
82-83	2.84E+03	1.14E+02	82-83	2.84E+03	2.73E+02	82-83	2.84E+03	1.77E+01
90	2.80E+04	1.13E+03	90	2.80E+04	2.70E+03	90	2.80E+04	1.75E+02
95-96	3.28E+04	1.32E+03	95-96	3.28E+04	3.15E+03	95-96	3.28E+04	2.05E+02
102-103	3.17E+04	1.27E+03	102-103	3.17E+04	3.05E+03	102-103	3.17E+04	1.98E+02
108-109	4.25E+04	1.71E+03	108-109	4.25E+04	4.09E+03	108-109	4.25E+04	2.66E+02
112	3.28E+04	1.32E+03	112	3.28E+04	3.16E+03	112	3.28E+04	2.05E+02
127.4	1.28E+04	5.15E+02	127.4	1.28E+04	1.23E+03	127.4	1.28E+04	8.01E+01
SX-113			**SX-115**			**S-104**		
Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)
33	1.00	2.28E-01	33	1.00	8.85E-02	33	1.00	3.89E-01
56.25	0.76	1.73E-01	56.25	0.76	6.73E-02	56.25	0.76	2.95E-01
57.5	3.10	7.06E-01	57.5	3.10	2.74E-01	57.5	3.10	1.21E+00
61.25	1.35	3.07E-01	61.25	1.35	1.19E-01	61.25	1.35	5.25E-01
62.75	5.25	1.20E+00	62.75	5.25	4.65E-01	62.75	5.25	2.04E+00
63.25	8.83	2.01E+00	63.25	8.83	7.81E-01	63.25	8.83	3.43E+00
63.75	11.34	2.58E+00	63.75	11.34	1.00E+00	63.75	11.34	4.41E+00
64.75	12.43	2.83E+00	64.75	12.43	1.10E+00	64.75	12.43	4.83E+00
68	19.93	4.54E+00	68	19.93	1.76E+00	68	19.93	7.75E+00
70	10.26	2.34E+00	70	10.26	9.08E-01	70	10.26	3.99E+00
71	27.85	6.34E+00	71	27.85	2.46E+00	71	27.85	1.08E+01
73.25	136.83	3.12E+01	73.25	136.83	1.21E+01	73.25	136.83	5.32E+01
73.75	400.86	9.13E+01	73.75	400.86	3.55E+01	73.75	400.86	1.56E+02
74.25	431.09	9.82E+01	74.25	431.09	3.81E+01	74.25	431.09	1.68E+02
75.25	321.44	7.32E+01	75.25	321.44	2.84E+01	75.25	321.44	1.25E+02
79.25	271.27	6.18E+01	79.25	271.27	2.40E+01	79.25	271.27	1.05E+02
79.75	275.95	6.28E+01	79.75	275.95	2.44E+01	79.75	275.95	1.07E+02
80.25	358.65	8.17E+01	80.25	358.65	3.17E+01	80.25	358.65	1.39E+02

Table E1.3. Vadose Zone Inventory Estimates for NO_3 for Individual Tanks (3 Sheets)

SX-113			SX-115			S-104		
Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)
87	73.51	1.67E+01	87	73.51	6.51E+00	87	73.51	2.86E+01
88.4	446.68	1.02E+02	88.4	446.68	3.95E+01	88.4	446.68	1.74E+02
95	340.37	7.75E+01	95	340.37	3.01E+01	95	340.37	1.32E+02
99	162.65	3.70E+01	99	162.65	1.44E+01	99	162.65	6.32E+01
100	423.71	9.65E+01	100	423.71	3.75E+01	100	423.71	1.65E+02
103.25	156.9	3.57E+01	103.25	156.9	1.39E+01	103.25	156.9	6.10E+01
105.25	75.31	1.72E+01	105.25	75.31	6.66E+00	105.25	75.31	2.93E+01
107	342.38	7.80E+01	107	342.38	3.03E+01	107	342.38	1.33E+02
116	467.69	1.07E+02	116	467.69	4.14E+01	116	467.69	1.82E+02
123.8			123.8			123.8		0.00E+00
124.35	864.67	1.97E+02	124.35	864.67	7.65E+01	124.35	864.67	3.36E+02
125.35	2179.74	4.96E+02	125.35	2179.74	1.93E+02	125.35	2179.74	8.47E+02
126.35	3304	7.52E+02	126.35	3304	2.92E+02	126.35	3304	1.28E+03
129.45	3932.54	8.96E+02	129.45	3932.54	3.48E+02	129.45	3932.54	1.53E+03
132.45	3195.73	7.28E+02	132.45	3195.73	2.83E+02	132.45	3195.73	1.24E+03
134.45	811.76	1.85E+02	134.45	811.76	7.18E+01	134.45	811.76	3.16E+02
136	2775.74	6.32E+02	136	2775.74	2.46E+02	136	2775.74	1.08E+03
138.2	2733.58	6.23E+02	138.2	2733.58	2.42E+02	138.2	2733.58	1.06E+03
140.65	2738.14	6.24E+02	140.65	2738.14	2.42E+02	140.65	2738.14	1.06E+03
141.65	2593.89	5.91E+02	141.65	2593.89	2.30E+02	141.65	2593.89	1.01E+03
142.75	2396.13	5.46E+02	142.75	2396.13	2.12E+02	142.75	2396.13	9.31E+02
144.2	1800.1	4.10E+02	144.2	1800.1	1.59E+02	144.2	1800.1	7.00E+02
145.65	1552.49	3.54E+02	145.65	1552.49	1.37E+02	145.65	1552.49	6.03E+02
146.65	2454.17	5.59E+02	146.65	2454.17	2.17E+02	146.65	2454.17	9.54E+02
147.55	761.89	1.74E+02	147.55	761.89	6.74E+01	147.55	761.89	2.96E+02
148.55	1385.37	3.16E+02	148.55	1385.37	1.23E+02	148.55	1385.37	5.39E+02
149.55	2140.04	4.87E+02	149.55	2140.04	1.89E+02	149.55	2140.04	8.32E+02
152.2	408.97	9.31E+01	152.2	408.97	3.62E+01	152.2	408.97	1.59E+02
153.15	229.2	5.22E+01	153.15	229.2	2.03E+01	153.15	229.2	8.91E+01
155.15	44.09	1.00E+01	155.15	44.09	3.90E+00	155.15	44.09	1.71E+01
156.1	292.81	6.67E+01	156.1	292.81	2.59E+01	156.1	292.81	1.14E+02
156.55	86.84	1.98E+01	156.55	86.84	7.68E+00	156.55	86.84	3.38E+01
157.75	3.56	8.11E-01	157.75	3.56	3.15E-01	157.75	3.56	1.38E+00
158.65	24.93	5.68E+00	158.65	24.93	2.21E+00	158.65	24.93	9.69E+00
159.75	32.24	7.34E+00	159.75	32.24	2.85E+00	159.75	32.24	1.25E+01
161	23.02	5.24E+00	161	23.02	2.04E+00	161	23.02	8.95E+00

Table E1.3. Vadose Zone Inventory Estimates for NO_3 for Individual Tanks (3 Sheets)

SX-113			SX-115			S-104		
Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)	Depth (ft) bgs	NO3 (ug/g soil)	NO3 (Kg)
162	28.29	6.44E+00	162	28.29	2.50E+00	162	28.29	1.10E+01
166	17.19	3.91E+00	166	17.19	1.52E+00	166	17.19	6.68E+00
167	11.36	2.59E+00	167	11.36	1.01E+00	167	11.36	4.42E+00
175	5.65	1.29E+00	175	5.65	5.00E-01	175	5.65	2.20E+00
185	3.87	8.81E-01	185	3.87	3.42E-01	185	3.87	1.50E+00
184.8	6.53	1.49E+00	184.8	6.53	5.78E-01	184.8	6.53	2.54E+00
186	0.78	1.78E-01	186	0.78	6.90E-02	186	0.78	3.03E-01
190	3.13	7.13E-01	190	3.13	2.77E-01	190	3.13	1.22E+00
194.55	1.14	2.60E-01	194.55	1.14	1.01E-01	194.55	1.14	4.43E-01
204.45	76.79	1.75E+01	204.45	76.79	6.80E+00	204.45	76.79	2.98E+01
205.1	25.29	5.76E+00	205.1	25.29	2.24E+00	205.1	25.29	9.83E+00

Table E1.4. Vadose Zone Inventory Estimates for Cr for Individual Tanks (3 Sheets)

SX-107			SX-108			SX-109		
Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)
25-26	5.00E-04	8.09E-05	25-26	5.00E-04	1.94E-04	25-26	5.00E-04	1.26E-05
44-45	2.89E-03	4.68E-04	44-45	2.89E-03	1.12E-03	44-45	2.89E-03	7.28E-05
56-57	3.42E-03	5.53E-04	56-57	3.42E-03	1.33E-03	56-57	3.42E-03	8.61E-05
61-62	8.15E-03	1.32E-03	61-62	8.15E-03	3.16E-03	61-62	8.15E-03	2.05E-04
65-66	3.43E-01	5.54E-02	65-66	3.43E-01	1.33E-01	65-66	3.43E-01	8.63E-03
69-70	5.07E+00	8.20E-01	69-70	5.07E+00	1.97E+00	69-70	5.07E+00	1.28E-01
74-75	4.09E+00	6.62E-01	74-75	4.09E+00	1.59E+00	74-75	4.09E+00	1.03E-01
79-80	7.17E-01	1.16E-01	79-80	7.17E-01	2.78E-01	79-80	7.17E-01	1.81E-02
82-83	7.45E+02	1.21E+02	82-83	7.45E+02	2.89E+02	82-83	7.45E+02	1.88E+01
90	7.12E+02	1.15E+02	90	7.12E+02	2.76E+02	90	7.12E+02	1.79E+01
95-96	2.60E+02	4.21E+01	95-96	2.60E+02	1.01E+02	95-96	2.60E+02	6.55E+00
102-103	5.28E+02	8.54E+01	102-103	5.28E+02	2.05E+02	102-103	5.28E+02	1.33E+01
108-109	4.81E+02	7.78E+01	108-109	4.81E+02	1.87E+02	108-109	4.81E+02	1.21E+01
112	1.75E+02	2.83E+01	112	1.75E+02	6.79E+01	112	1.75E+02	4.41E+00
127.4	1.15E-02	1.86E-03	127.4	1.15E-02	4.46E-03	127.4	1.15E-02	2.90E-04
SX-113			**SX-115**			**S-104**		
Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)
33	2.50E-03	1.46E-02	33	2.50E-03	1.45E-02	33	2.50E-03	2.25E-02
56.25	5.00E-04	2.92E-03	56.25	5.00E-04	2.89E-03	56.25	5.00E-04	4.49E-03
57.5	5.00E-04	2.92E-03	57.5	5.00E-04	2.89E-03	57.5	5.00E-04	4.49E-03
61.25	5.13E-04	2.99E-03	61.25	5.13E-04	2.96E-03	61.25	5.13E-04	4.60E-03
62.75	5.01E-04	2.92E-03	62.75	5.01E-04	2.89E-03	62.75	5.01E-04	4.49E-03
63.25	1.44E-03	8.38E-03	63.25	1.44E-03	8.30E-03	63.25	1.44E-03	1.29E-02
63.75	1.29E-03	7.54E-03	63.75	1.29E-03	7.46E-03	63.75	1.29E-03	1.16E-02
64.75	5.02E-04	2.93E-03	64.75	5.02E-04	2.90E-03	64.75	5.02E-04	4.51E-03
68	1.67E-02	9.77E-02	68	1.67E-02	9.67E-02	68	1.67E-02	1.50E-01
70	3.02E-02	1.76E-01	70	3.02E-02	1.75E-01	70	3.02E-02	2.71E-01
71	5.01E-01	2.93E+00	71	5.01E-01	2.90E+00	71	5.01E-01	4.50E+00
73.25	1.56E+00	9.12E+00	73.25	1.56E+00	9.03E+00	73.25	1.56E+00	1.40E+01
73.75	5.00E+00	2.92E+01	73.75	5.00E+00	2.89E+01	73.75	5.00E+00	4.49E+01
74.25	6.85E+00	4.00E+01	74.25	6.85E+00	3.96E+01	74.25	6.85E+00	6.15E+01
75.25	3.16E+00	1.85E+01	75.25	3.16E+00	1.83E+01	75.25	3.16E+00	2.84E+01
79.25	3.63E+00	2.12E+01	79.25	3.63E+00	2.10E+01	79.25	3.63E+00	3.26E+01
79.75	2.72E+00	1.59E+01	79.75	2.72E+00	1.58E+01	79.75	2.72E+00	2.45E+01
80.25	3.31E+00	1.93E+01	80.25	3.31E+00	1.91E+01	80.25	3.31E+00	2.97E+01

Table E1.4. Vadose Zone Inventory Estimates for Cr for Individual Tanks (3 Sheets)

SX-113			SX-115			S-104		
Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)
87	4.13E-01	2.41E+00	87	4.13E-01	2.39E+00	87	4.13E-01	3.71E+00
88.4	6.47E+00	3.78E+01	88.4	6.47E+00	3.74E+01	88.4	6.47E+00	5.81E+01
95	3.77E+00	2.20E+01	95	3.77E+00	2.18E+01	95	3.77E+00	3.39E+01
99	1.84E+00	1.07E+01	99	1.84E+00	1.06E+01	99	1.84E+00	1.65E+01
100	7.51E+00	4.39E+01	100	7.51E+00	4.34E+01	100	7.51E+00	6.74E+01
103.25	2.61E+00	1.52E+01	103.25	2.61E+00	1.51E+01	103.25	2.61E+00	2.34E+01
105.25	1.32E+00	7.69E+00	105.25	1.32E+00	7.62E+00	105.25	1.32E+00	1.18E+01
107	8.15E+00	4.76E+01	107	8.15E+00	4.71E+01	107	8.15E+00	7.31E+01
116	6.85E+00	4.00E+01	116	6.85E+00	3.96E+01	116	6.85E+00	6.15E+01
123.8	7.30E+00	4.26E+01	123.8	7.30E+00	4.22E+01	123.8	7.30E+00	6.55E+01
124.35	7.30E+00	4.26E+01	124.35	7.30E+00	4.22E+01	124.35	7.30E+00	6.55E+01
125.35	6.27E+00	3.66E+01	125.35	6.27E+00	3.63E+01	125.35	6.27E+00	5.63E+01
126.35	3.62E-01	2.12E+00	126.35	3.62E-01	2.09E+00	126.35	3.62E-01	3.25E+00
129.45	4.30E-03	2.51E-02	129.45	4.30E-03	2.49E-02	129.45	4.30E-03	3.86E-02
132.45	5.01E-04	2.93E-03	132.45	5.01E-04	2.90E-03	132.45	5.01E-04	4.50E-03
134.45	4.04E-04	2.36E-03	134.45	4.04E-04	2.34E-03	134.45	4.04E-04	3.63E-03
136	2.50E-03	1.46E-02	136	2.50E-03	1.45E-02	136	2.50E-03	2.24E-02
138.2	2.50E-03	1.46E-02	138.2	2.50E-03	1.45E-02	138.2	2.50E-03	2.25E-02
140.65	2.50E-03	1.46E-02	140.65	2.50E-03	1.45E-02	140.65	2.50E-03	2.24E-02
141.65	2.50E-03	1.46E-02	141.65	2.50E-03	1.45E-02	141.65	2.50E-03	2.25E-02
142.75	1.05E-03	6.16E-03	142.75	1.05E-03	6.10E-03	142.75	1.05E-03	9.47E-03
144.2	8.57E-04	5.01E-03	144.2	8.57E-04	4.96E-03	144.2	8.57E-04	7.70E-03
145.65	2.50E-03	1.46E-02	145.65	2.50E-03	1.44E-02	145.65	2.50E-03	2.24E-02
146.65	9.63E-04	5.62E-03	146.65	9.63E-04	5.57E-03	146.65	9.63E-04	8.64E-03
147.55	1.47E-04	8.58E-04	147.55	1.47E-04	8.50E-04	147.55	1.47E-04	1.32E-03
148.55	1.48E-03	8.66E-03	148.55	1.48E-03	8.57E-03	148.55	1.48E-03	1.33E-02
149.55	2.50E-03	1.46E-02	149.55	2.50E-03	1.45E-02	149.55	2.50E-03	2.24E-02
152.2	9.33E-04	5.45E-03	152.2	9.33E-04	5.39E-03	152.2	9.33E-04	8.37E-03
153.15	6.76E-04	3.95E-03	153.15	6.76E-04	3.91E-03	153.15	6.76E-04	6.07E-03
155.15	5.00E-04	2.92E-03	155.15	5.00E-04	2.89E-03	155.15	5.00E-04	4.49E-03
156.1	1.04E-03	6.08E-03	156.1	1.04E-03	6.02E-03	156.1	1.04E-03	9.34E-03
156.55	2.50E-03	1.46E-02	156.55	2.50E-03	1.45E-02	156.55	2.50E-03	2.25E-02
157.75	5.08E-04	2.97E-03	157.75	5.08E-04	2.94E-03	157.75	5.08E-04	4.56E-03
158.65	1.02E-03	5.95E-03	158.65	1.02E-03	5.89E-03	158.65	1.02E-03	9.14E-03
159.75	5.42E-03	3.17E-02	159.75	5.42E-03	3.13E-02	159.75	5.42E-03	4.87E-02
161	2.96E-03	1.73E-02	161	2.96E-03	1.71E-02	161	2.96E-03	2.65E-02

Table E1.4. Vadose Zone Inventory Estimates for Cr for Individual Tanks (3 Sheets)

SX-113			SX-115			S-104		
Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)	Depth (ft) bgs	Cr (ug/g soil)	Cr (Kg)
162	4.37E-03	2.55E-02	162	4.37E-03	2.53E-02	162	4.37E-03	3.92E-02
166	1.23E-03	7.19E-03	166	1.23E-03	7.12E-03	166	1.23E-03	1.11E-02
167	6.00E-04	3.51E-03	167	6.00E-04	3.47E-03	167	6.00E-04	5.39E-03
175	2.36E-04	1.38E-03	175	2.36E-04	1.36E-03	175	2.36E-04	2.12E-03
185	1.01E-03	5.87E-03	185	1.01E-03	5.81E-03	185	1.01E-03	9.03E-03
184.8	7.09E-04	4.14E-03	184.8	7.09E-04	4.10E-03	184.8	7.09E-04	6.37E-03
186			186			186		
190	1.47E-04	8.59E-04	190	1.47E-04	8.51E-04	190	1.47E-04	1.32E-03
194.55	5.41E-04	3.16E-03	194.55	5.41E-04	3.13E-03	194.55	5.41E-04	4.86E-03
204.45	5.00E-04	2.92E-03	204.45	5.00E-04	2.89E-03	204.45	5.00E-04	4.49E-03
205.1	5.72E-04	3.34E-03	205.1	5.72E-04	3.31E-03	205.1	5.72E-04	5.14E-03

ATTACHMENT E2

INVENTORY DISTRIBUTIONS

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E2.1.0 UNIFORM INITIAL INVENTORY DISTRIBUTIONS

Color-scaled images of the uniform initial inventory distributions for the contaminant species (i.e., cesium-137, technetium-99, chromium, and nitrate) are shown in Figures E2.1 through E2.12 for cross-sections SX-DD', SX-FF', and S-CC'. The uniform inventory distributions conserve both the concentration and integrated mass records for each elevation bin by varying the distribution radius. Inventories are assumed to be distributed at each grid elevation as a circular disk.

Figure E2.1. Initial Cs-137 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

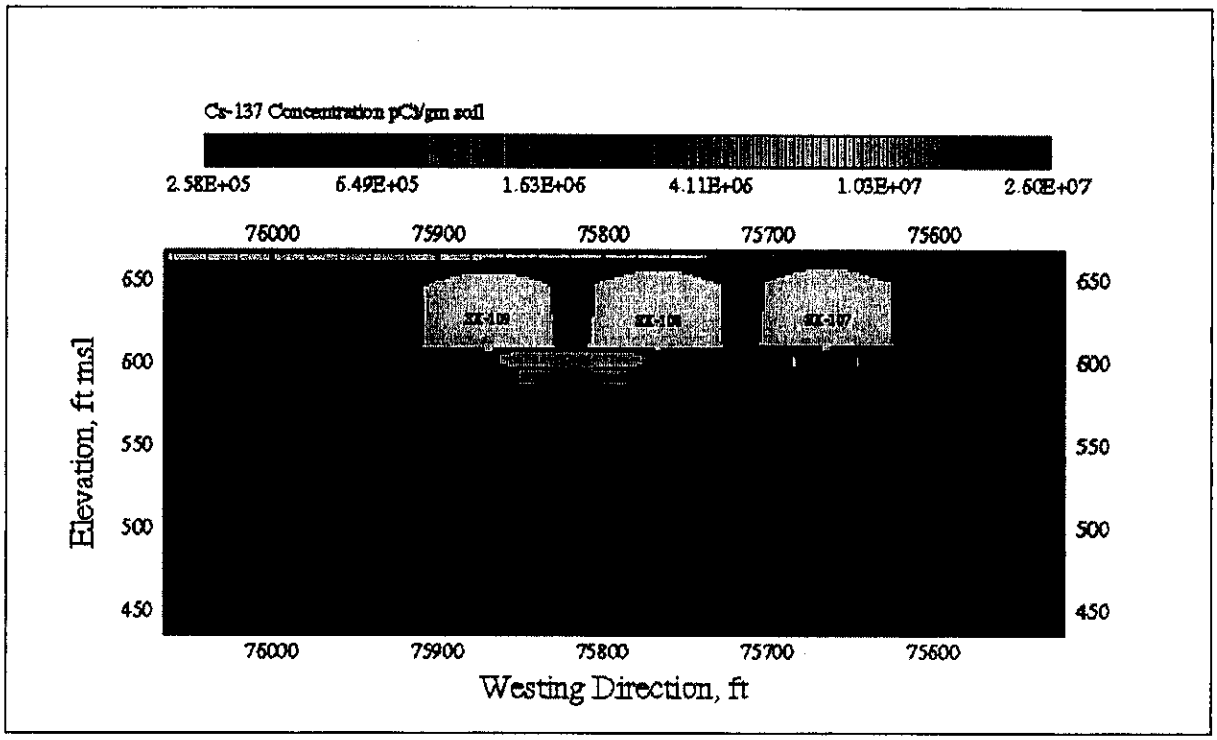


Figure E2.2. Initial Tc-99 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

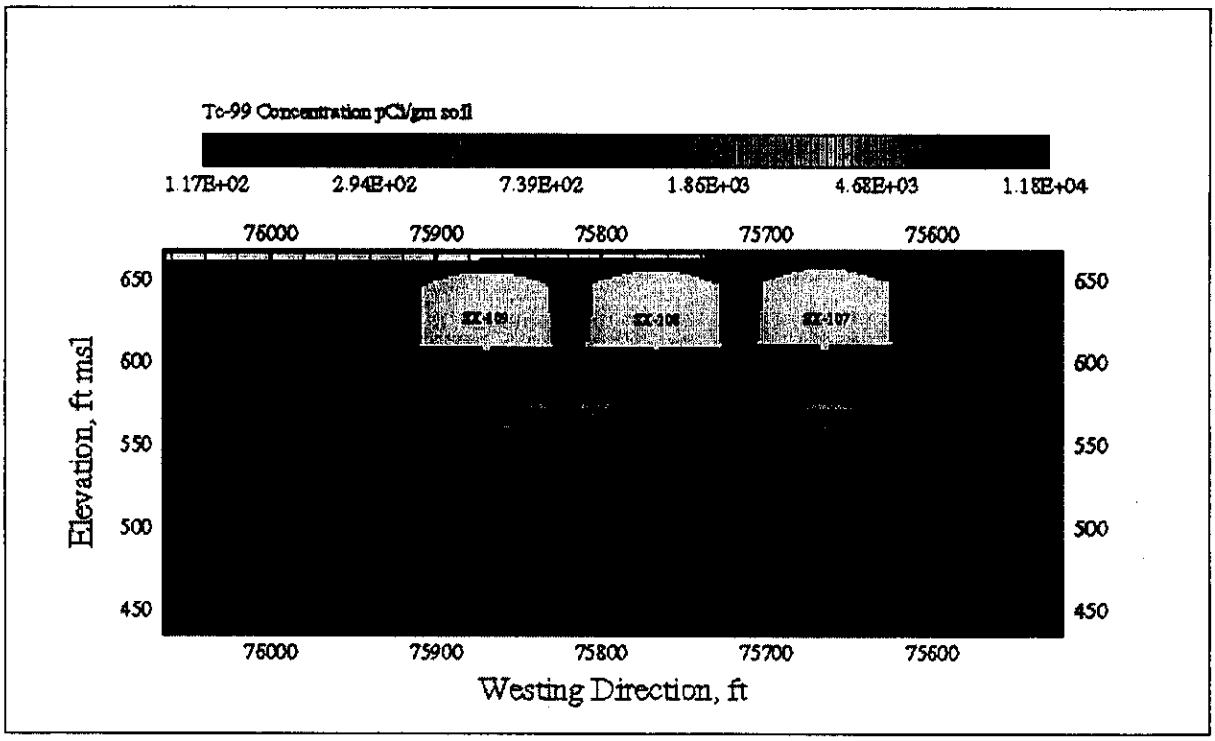


Figure E2.3. Initial Cr Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

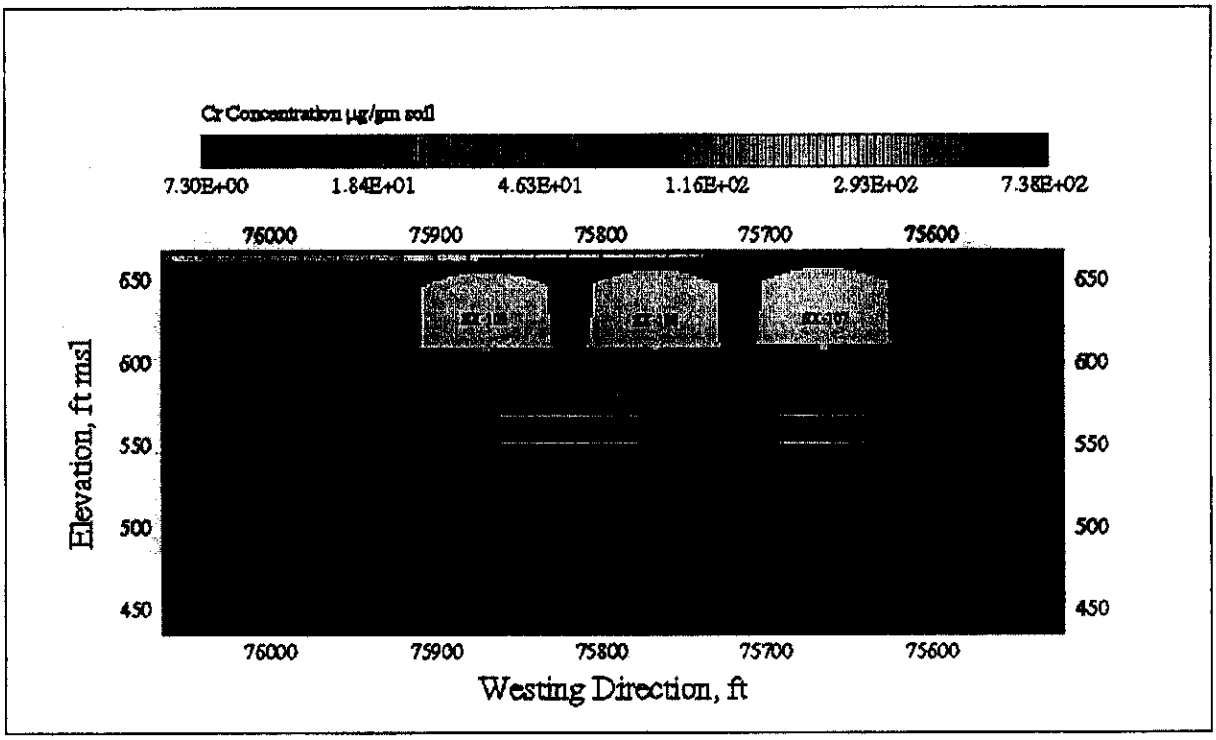


Figure E2.4. Initial NO_3 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

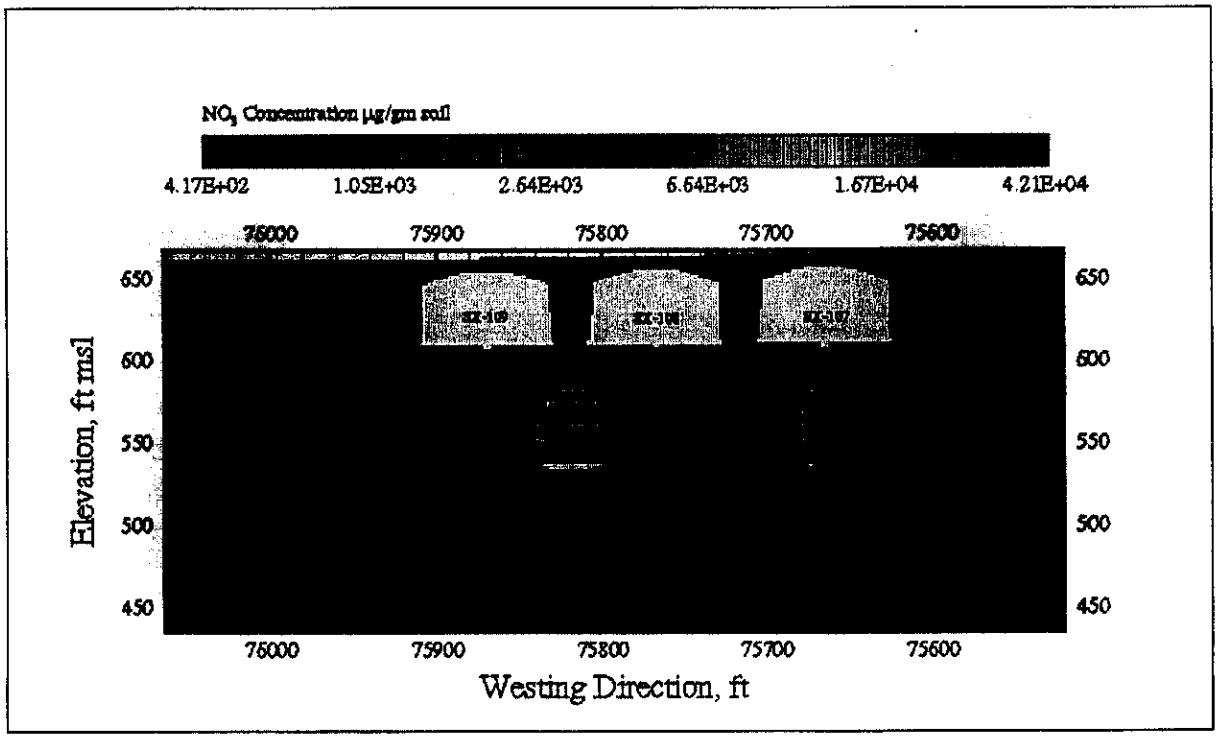


Figure E2.5. Initial Cs-137 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

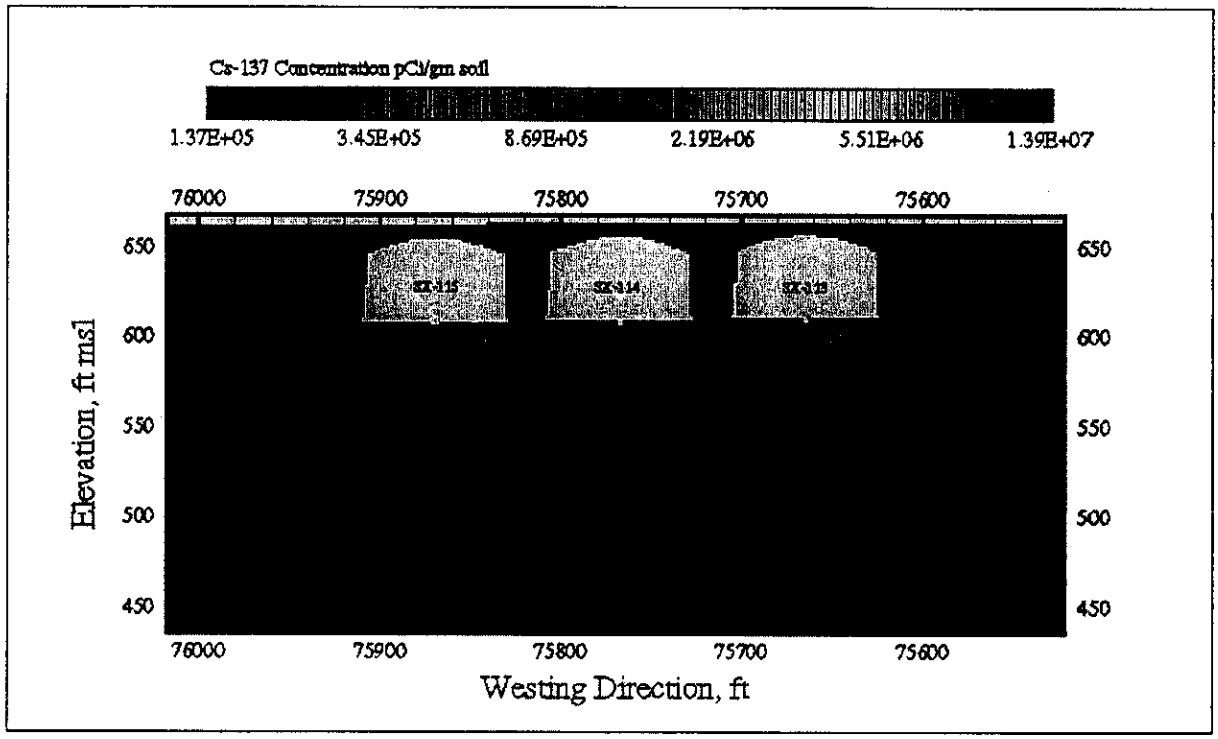


Figure E2.6. Initial Tc-99 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

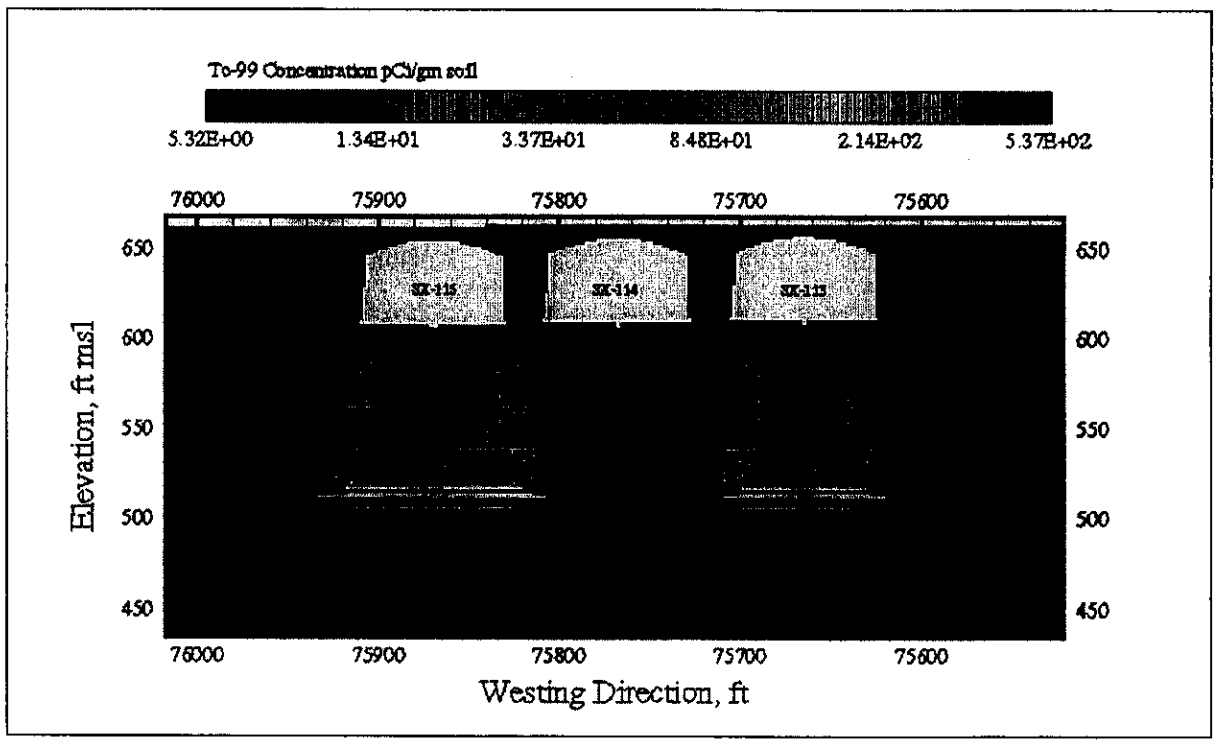


Figure E2.7. Initial Cr Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

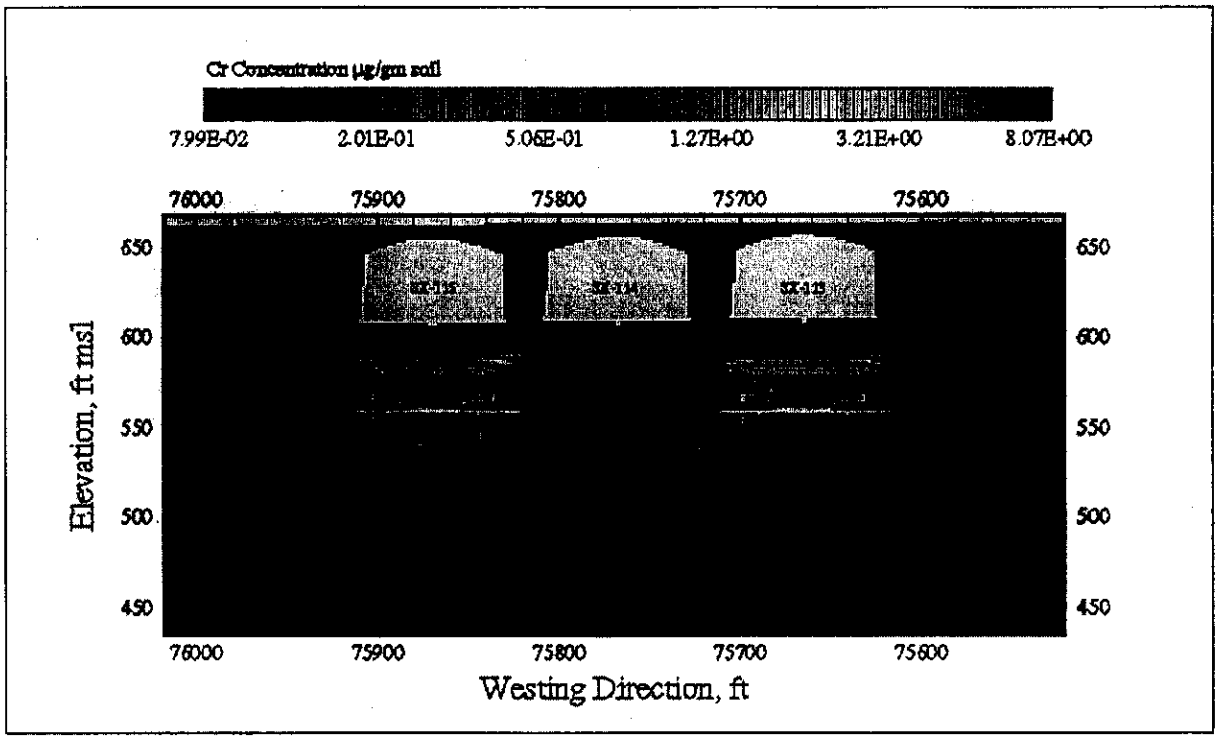


Figure E2.8. Initial NO_3 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

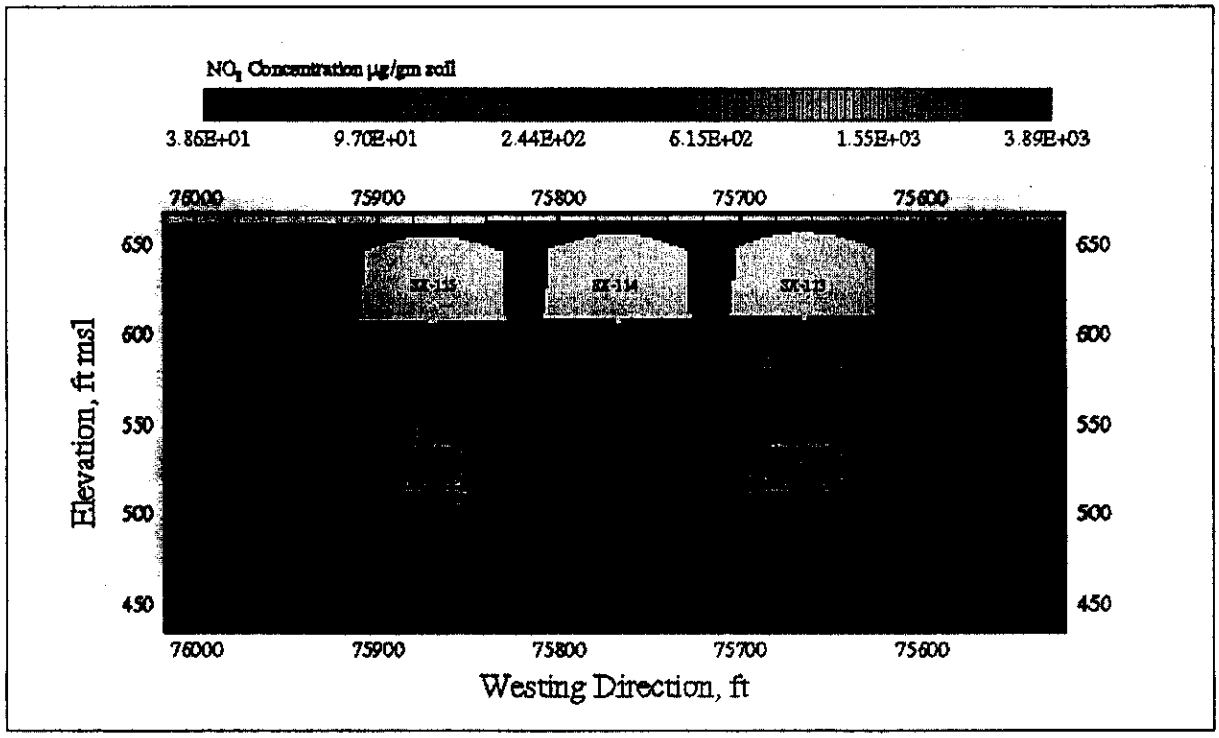


Figure E2.9. Initial Cs-137 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section S-CC' (S-104, -105, -106)

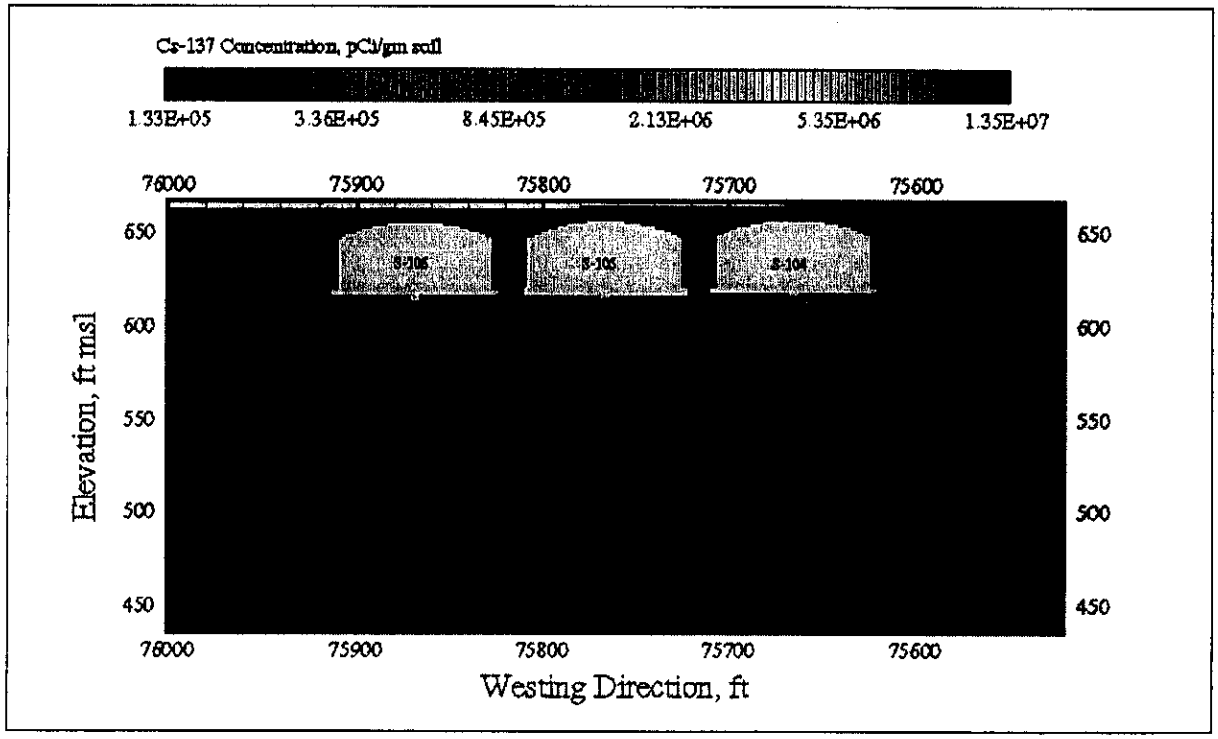


Figure E2.10. Initial Tc-99 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section S-CC' (S-104, -105, -106)

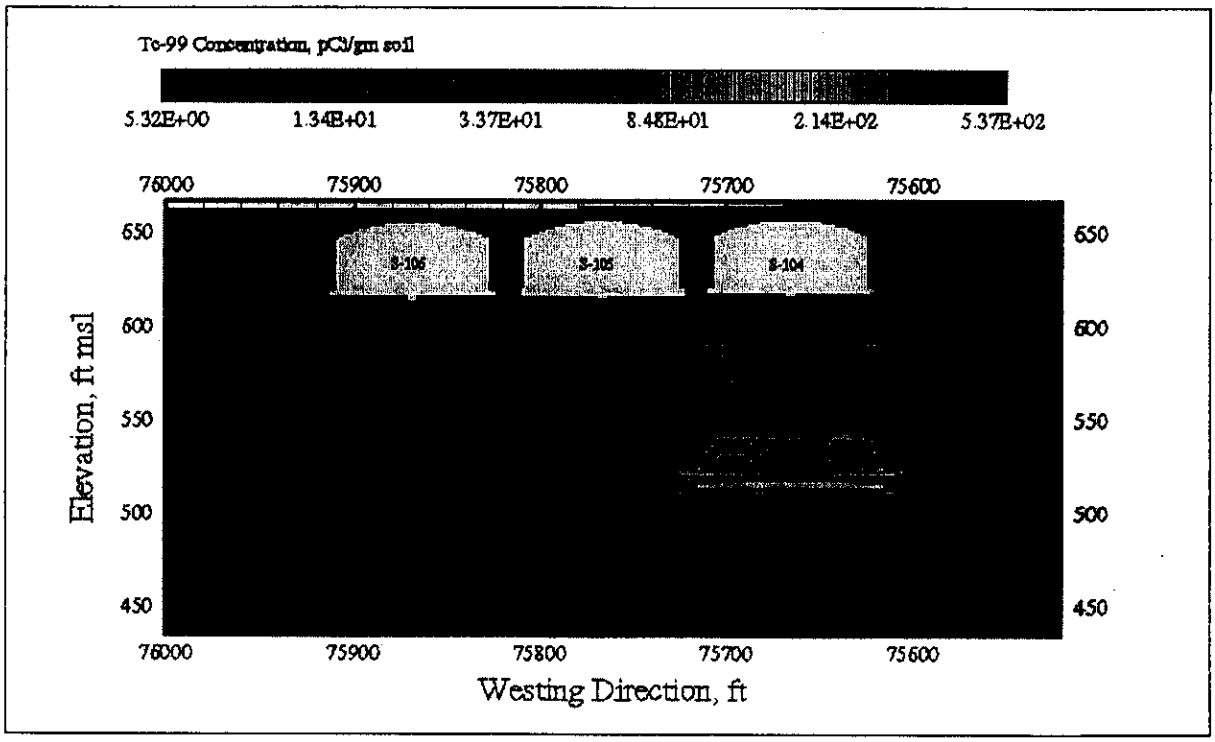


Figure E2.11. Initial Cr Aqueous-Phase Concentration, Uniform Distribution, Cross-Section S-CC' (S-104, -105, -106)

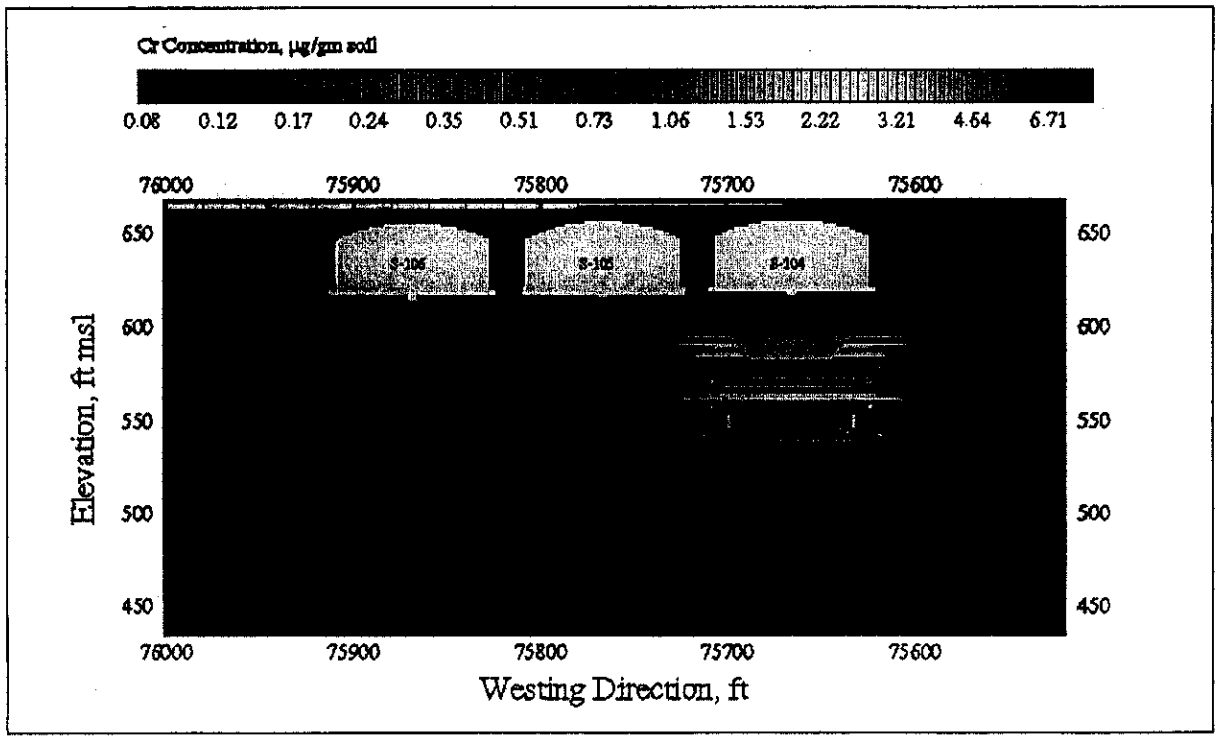
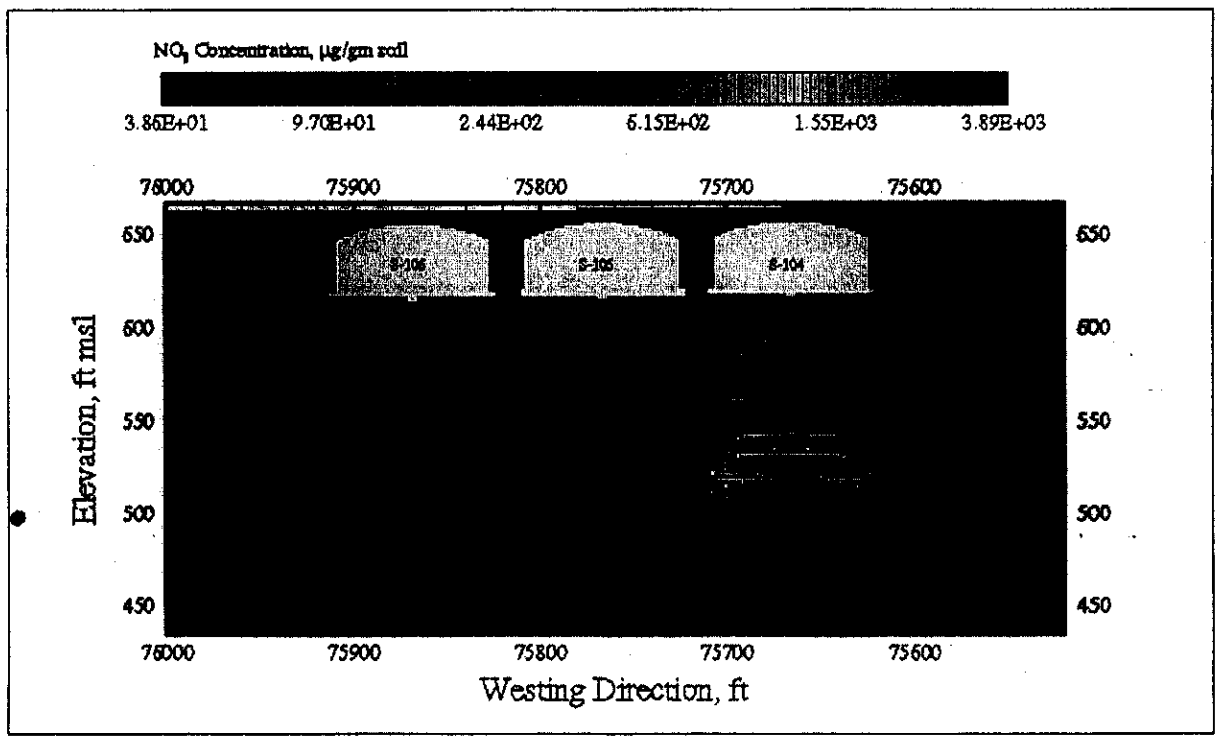


Figure E2.12. Initial NO_3 Aqueous-Phase Concentration, Uniform Distribution, Cross-Section S-CC' (S-104, -105, -106)



E2.2.0 NONUNIFORM INITIAL INVENTORY DISTRIBUTIONS

Color-scaled images of the nonuniform initial inventory distributions for the contaminant species (i.e., cesium-137, technetium-99, chromium, and nitrate) are shown in Figures E2.13 through E2.24 for cross-sections SX-DD', SX-FF', and S-CC'. The nonuniform inventory distributions conserve the integrated mass records for each elevation, but with a localized concentration. Inventory concentrations are generally higher than the concentration records at each elevation. Inventories are assumed to be distributed at each grid elevation as a circular disk.

Figure E2.13. Initial Cs-137 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

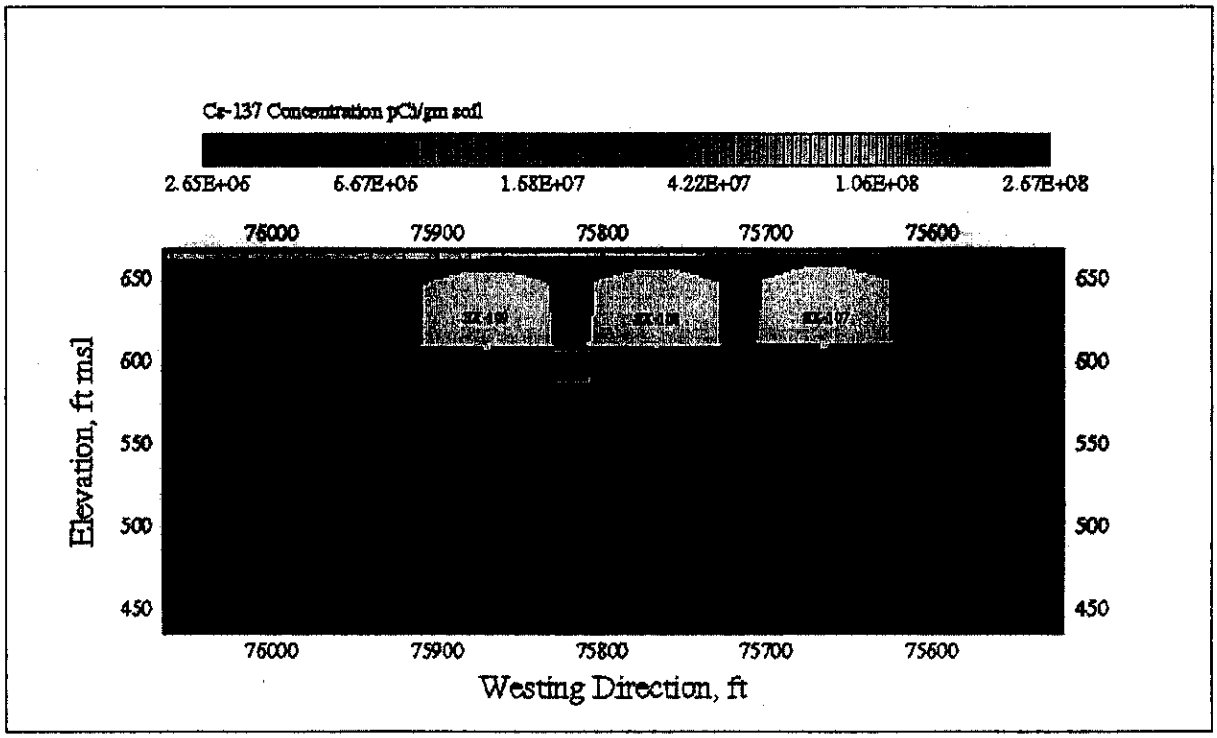


Figure E2.14. Initial Tc-99 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

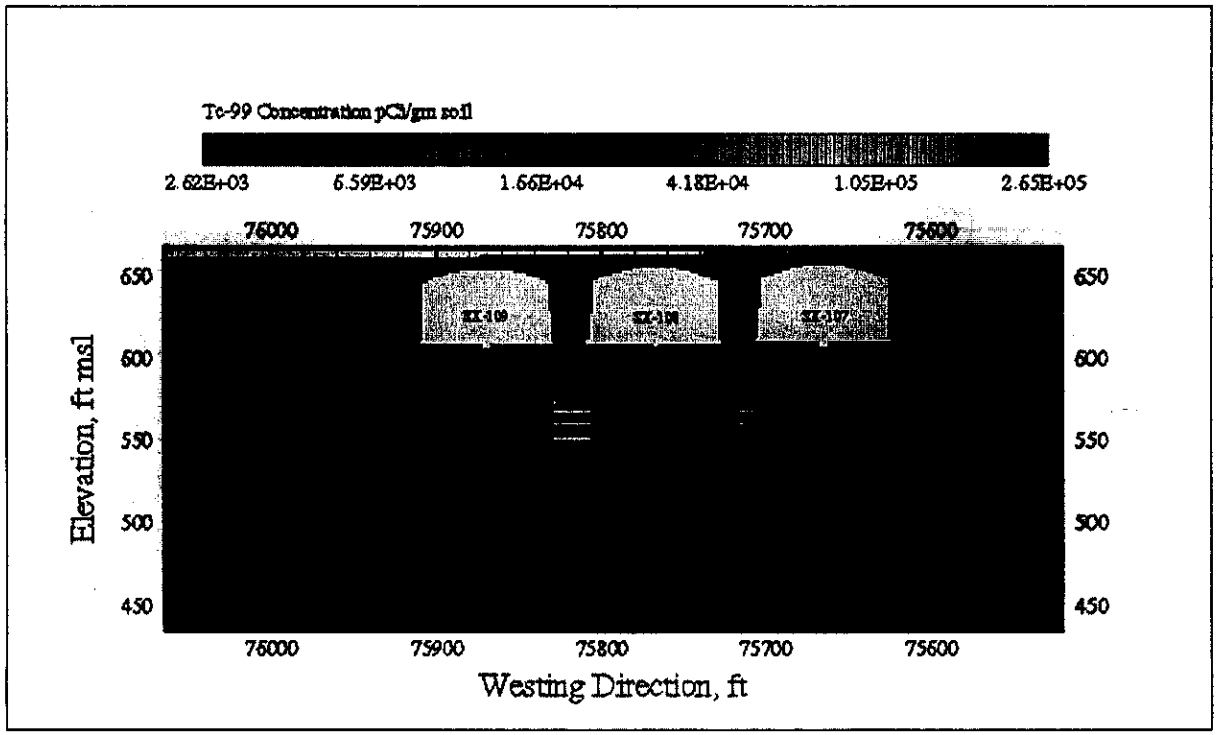


Figure E2.15. Initial Cr Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

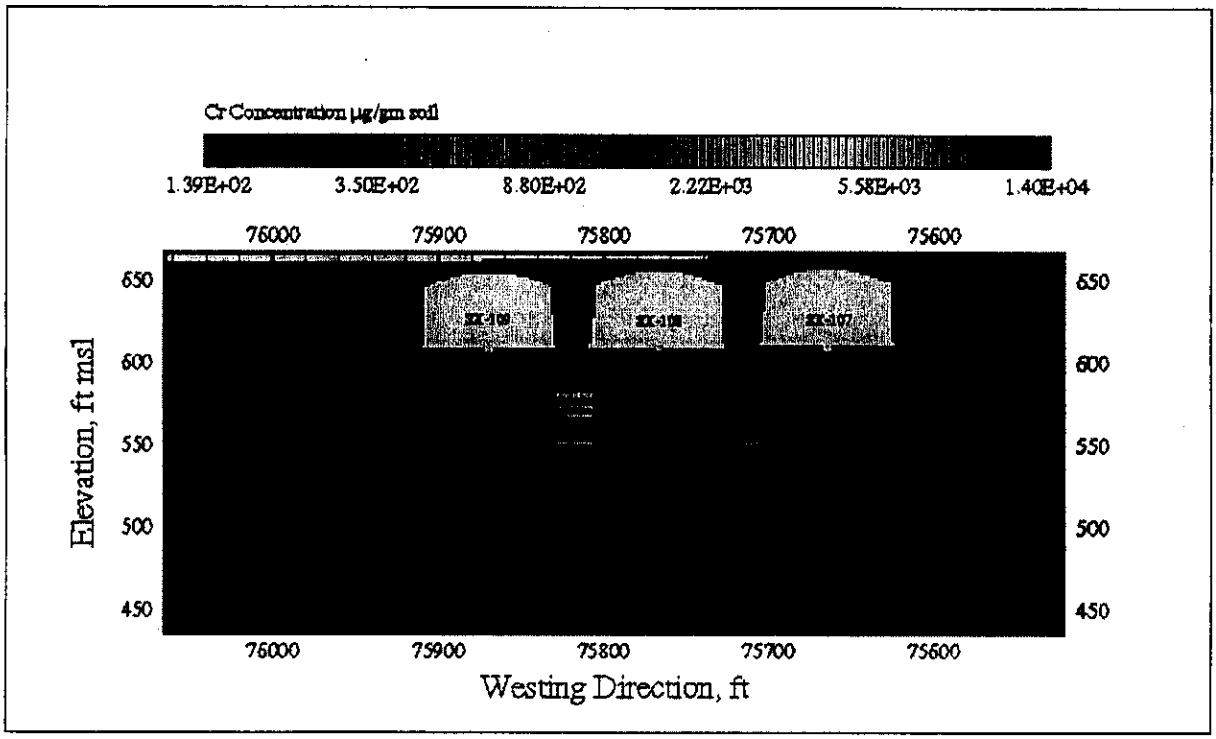


Figure E2.16. Initial NO_3 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

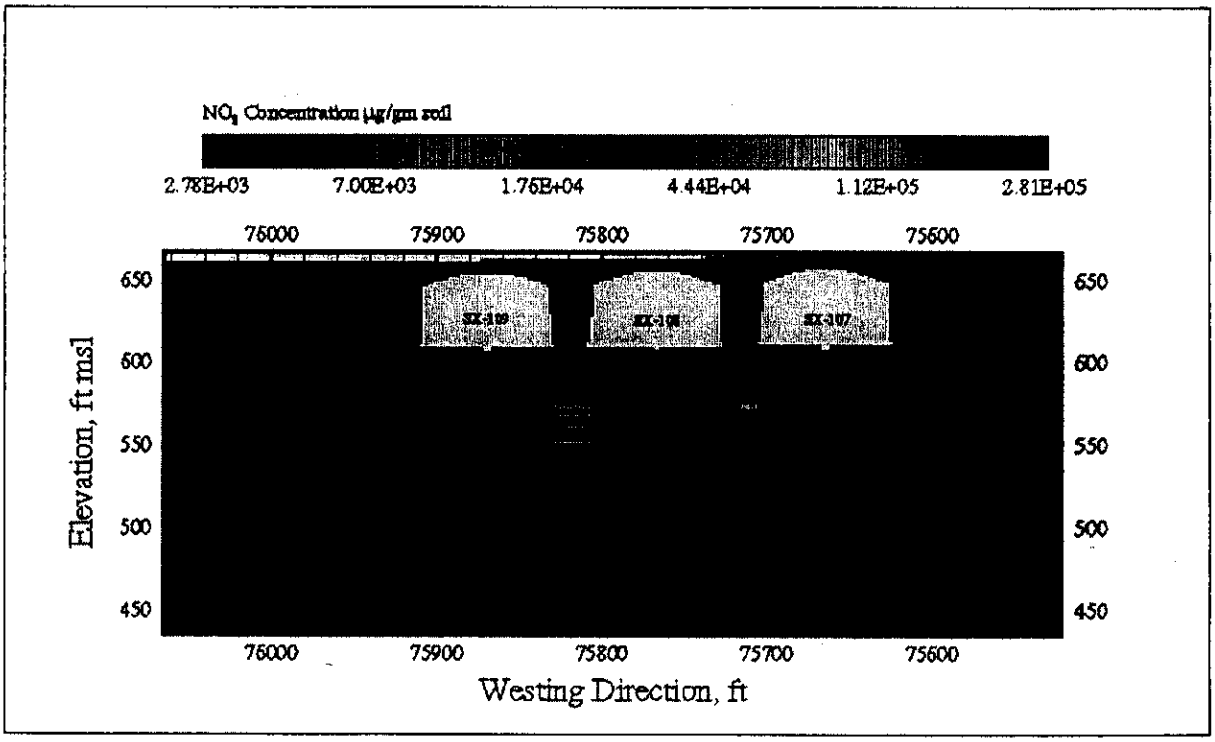


Figure E2.17. Initial Cs-137 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

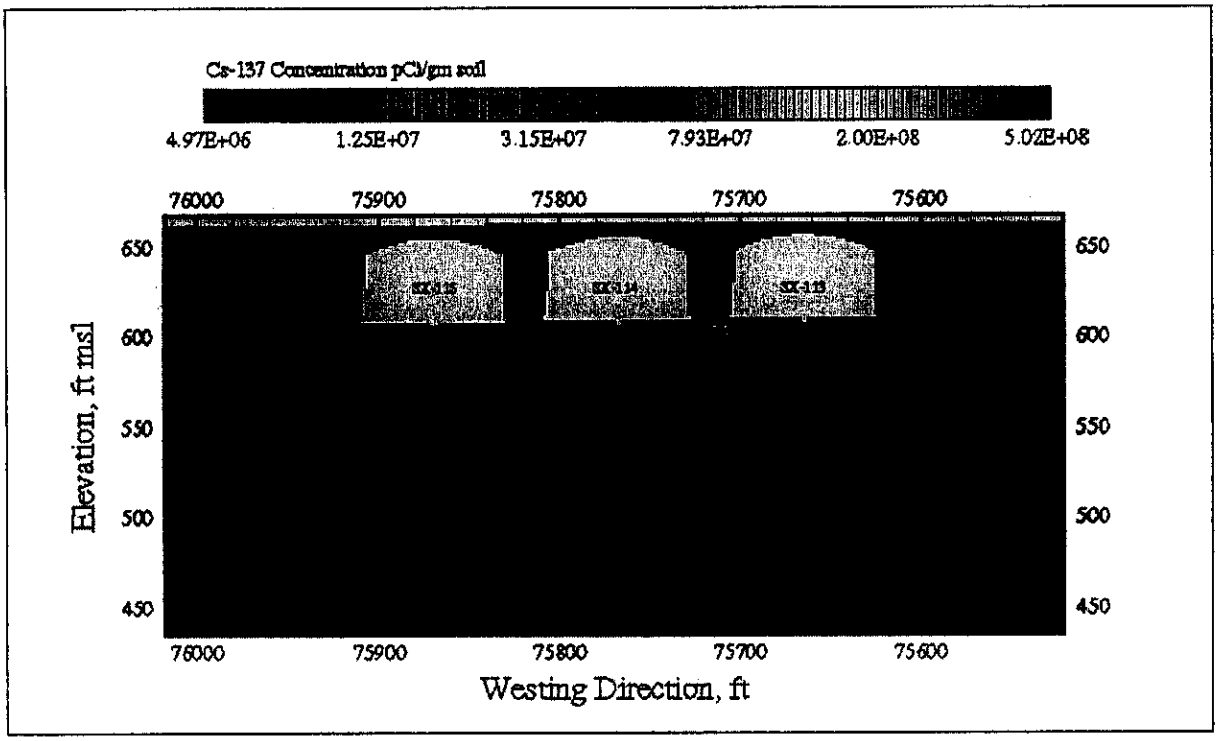


Figure E2.18. Initial Tc-99 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

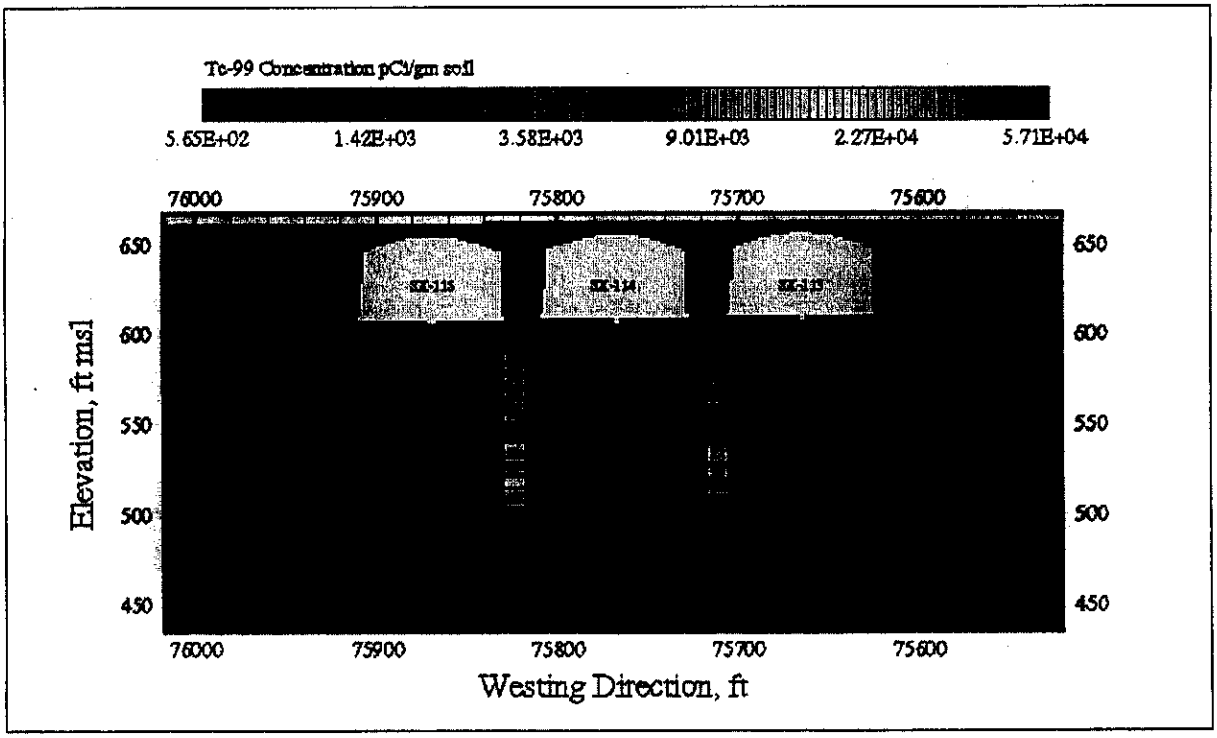


Figure E2.19. Initial Cr Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

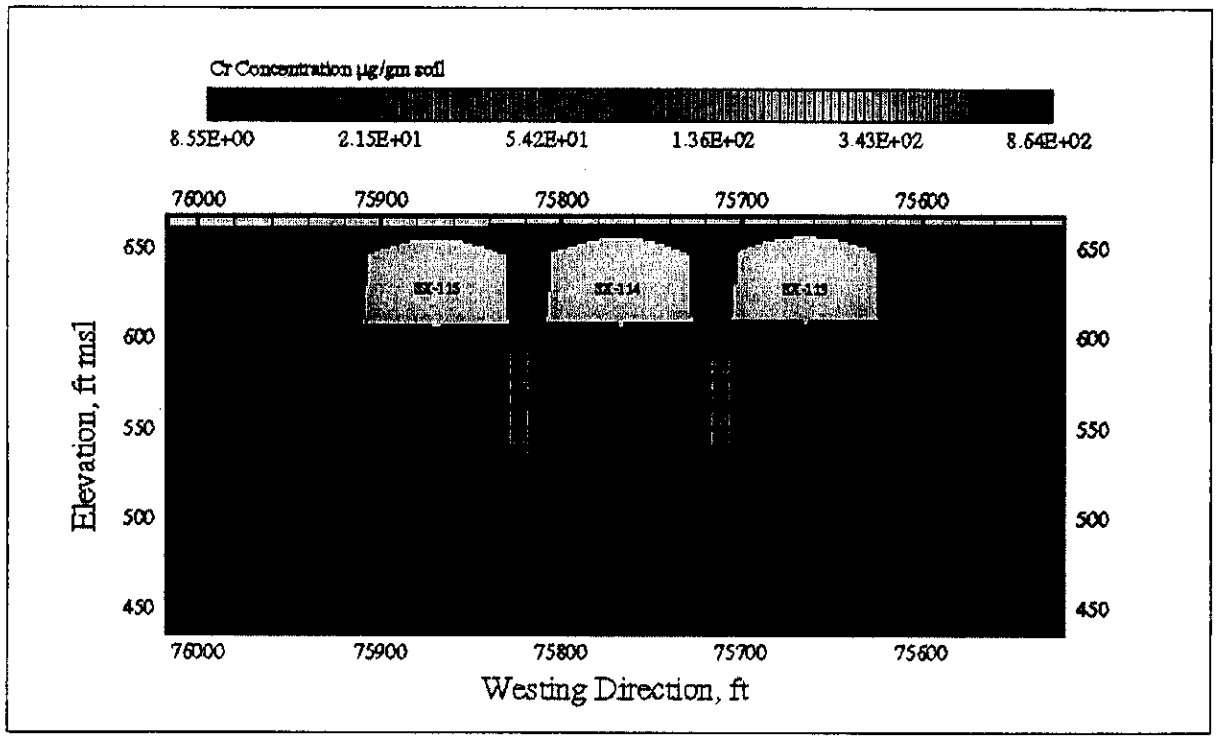


Figure E2.20. Initial NO_3 Aqueous-Phase Concentration, Nonuniform Distribution, Cross Section SX-FF' (SX-113, -114, -115)

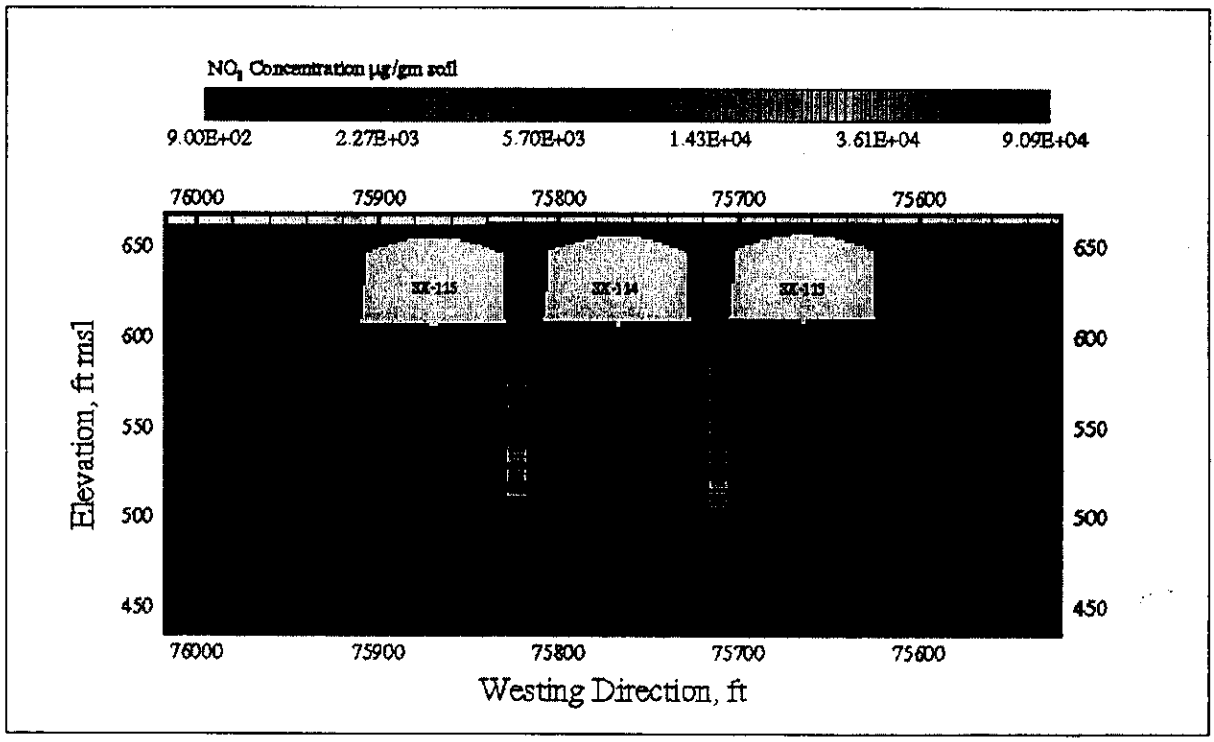


Figure E2.21. Initial Cs-137 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section S-CC' (S-104, -105, -106)

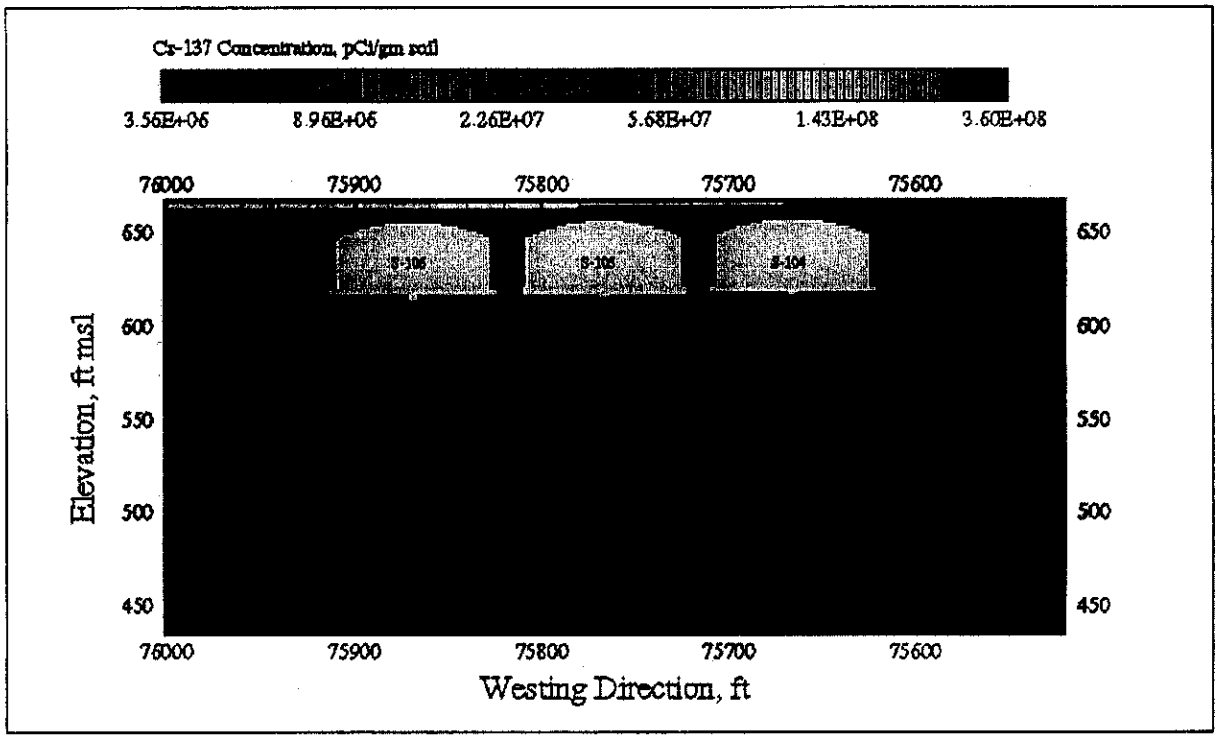


Figure E2.22. Initial Tc-99 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section S-CC' (S-104, -105, -106)

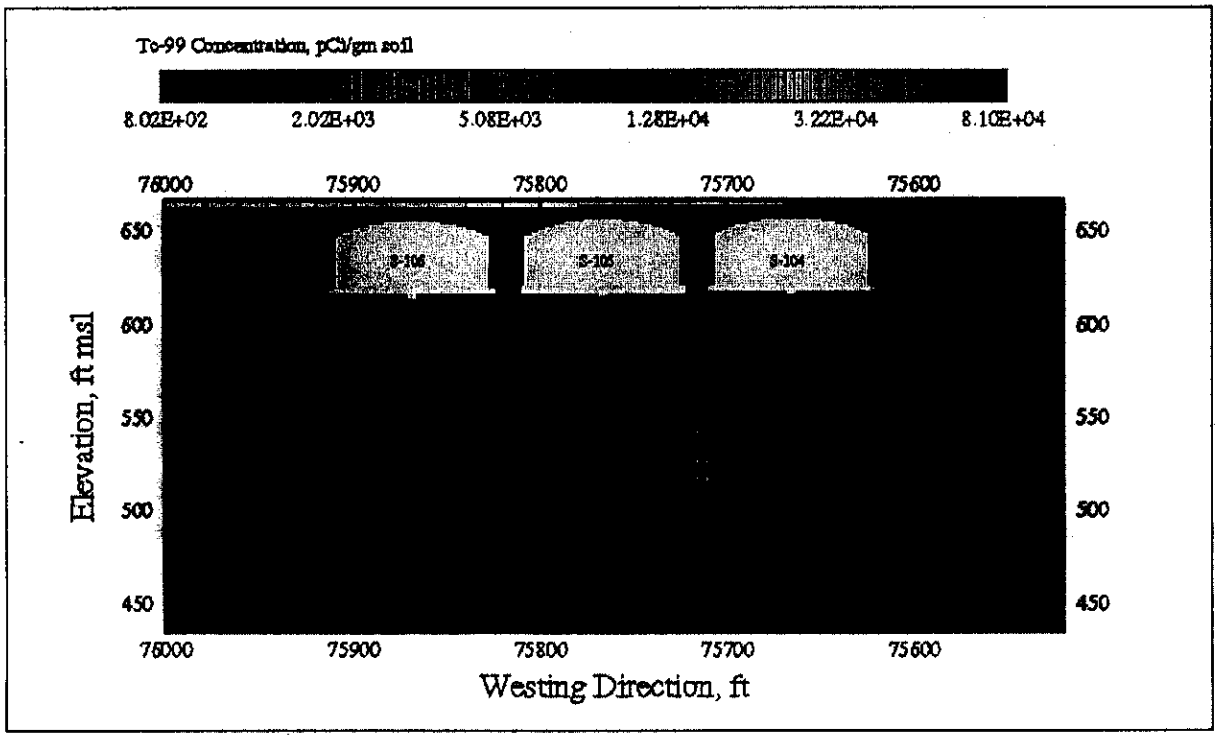


Figure E2.23. Initial Cr Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section S-CC' (S-104, -105, -106)

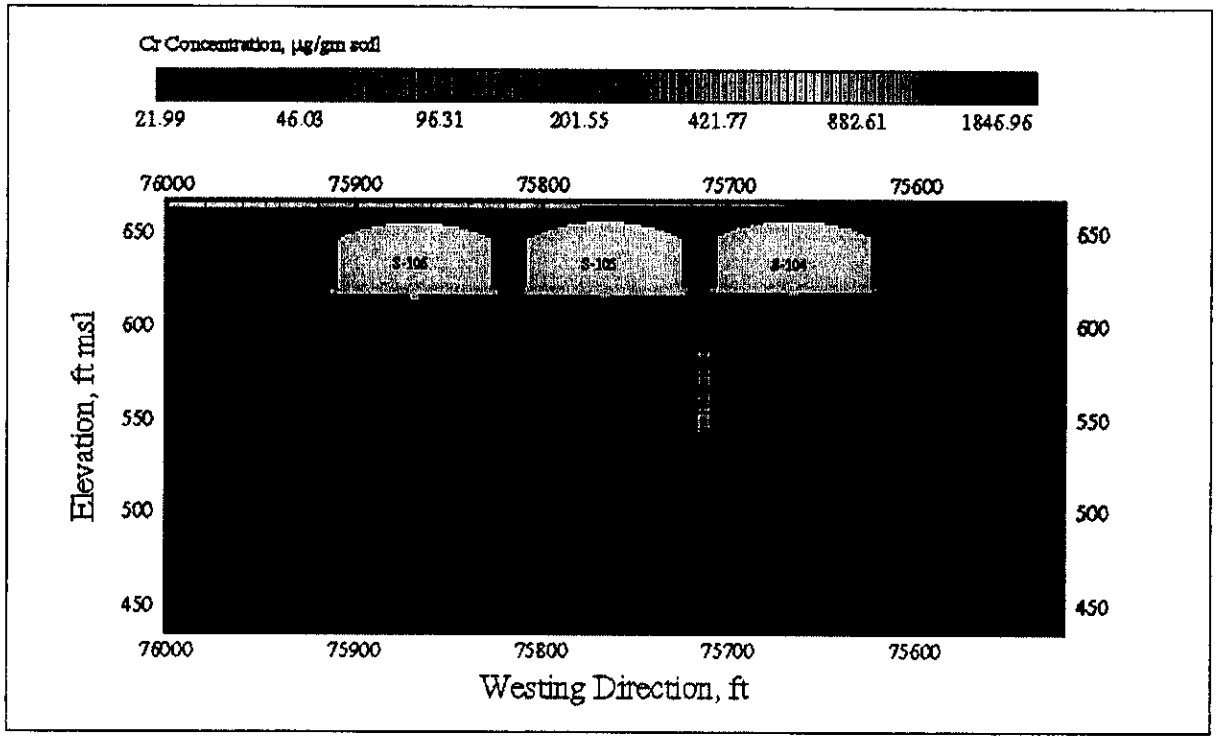
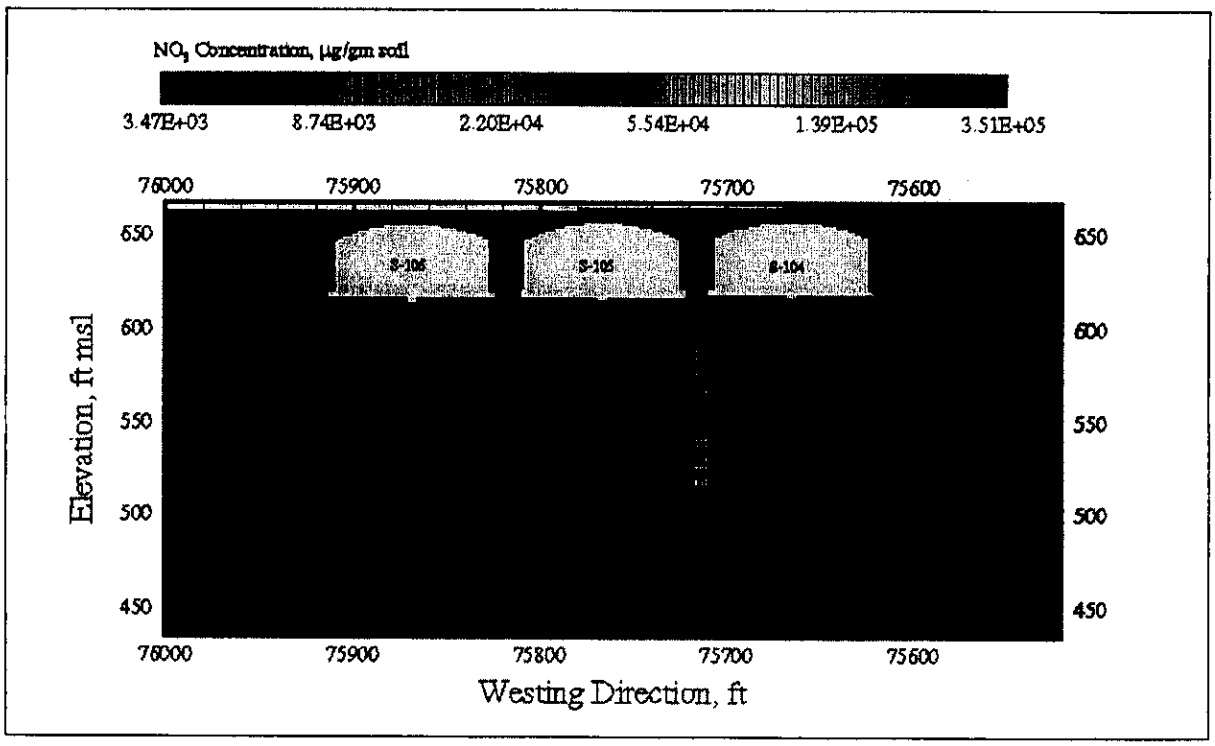


Figure E2.24. Initial NO_3 Aqueous-Phase Concentration, Nonuniform Distribution, Cross-Section S-CC' (S-104, -105, -106)



E2.3.0 DISPLACED INITIAL INVENTORY DISTRIBUTIONS

Color-scaled images of the displaced initial inventory distributions for the contaminant species (i.e., cesium-137, technetium-99, chromium, and nitrate) are shown in Figures E2.25 through E2.36 for cross-sections SX-DD', SX-FF', and S-CC'. The displaced inventory distributions conserve the integrated mass records for each elevation, but with a localized and displaced concentration. Inventory concentrations are generally higher than the concentration records at each corresponding undisplaced elevation. Inventories are assumed to be distributed at each grid elevation as a circular disk.

Figure E2.25. Initial Cs-137 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

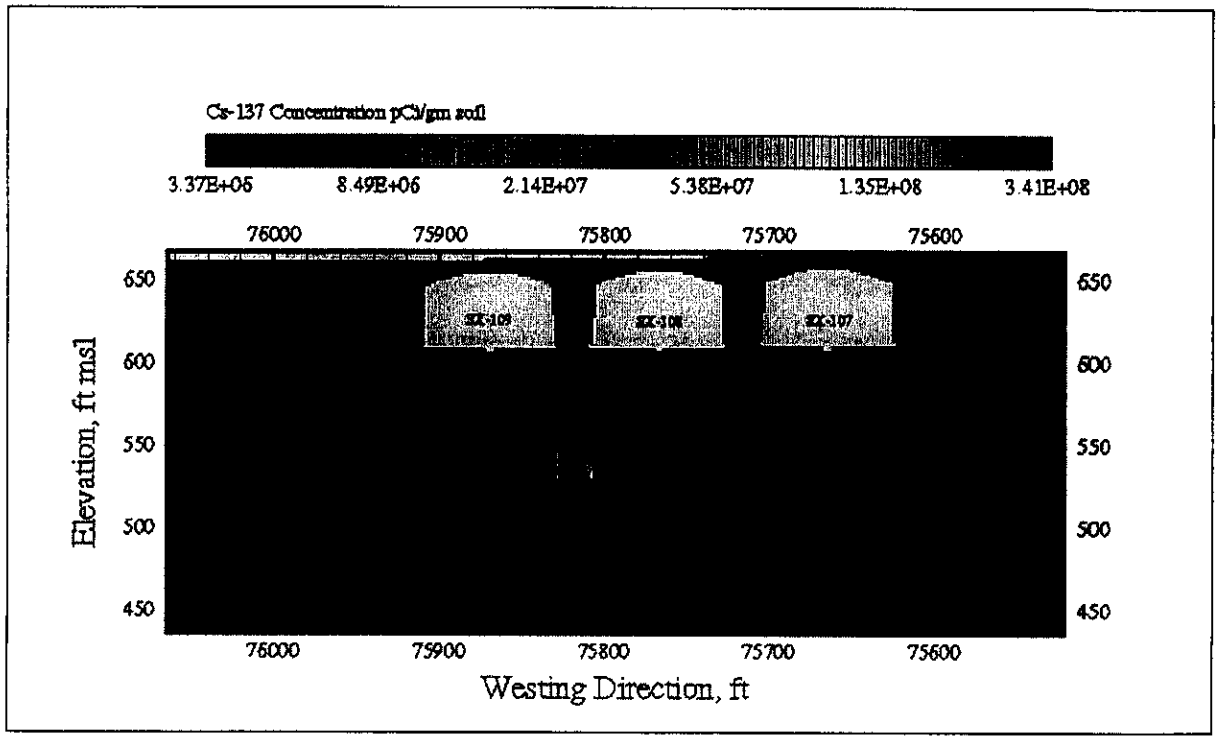


Figure E2.26. Initial Tc-99 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

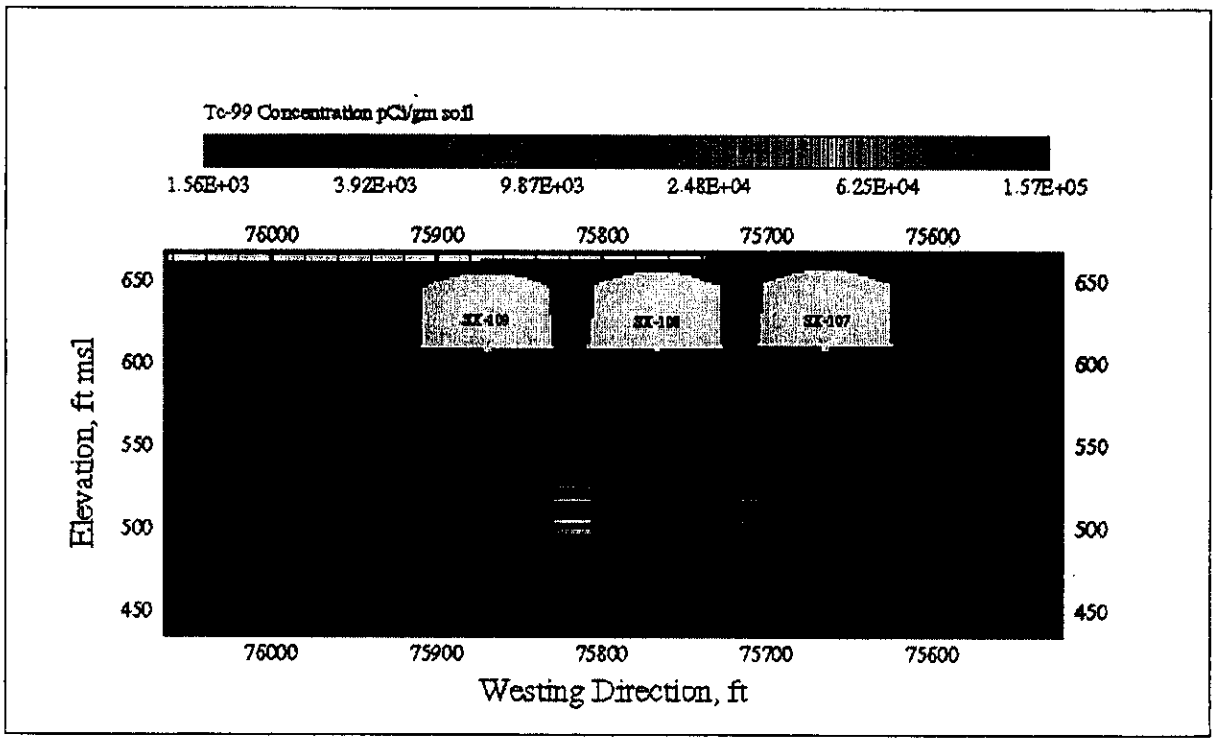


Figure E2.27. Initial Cr Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

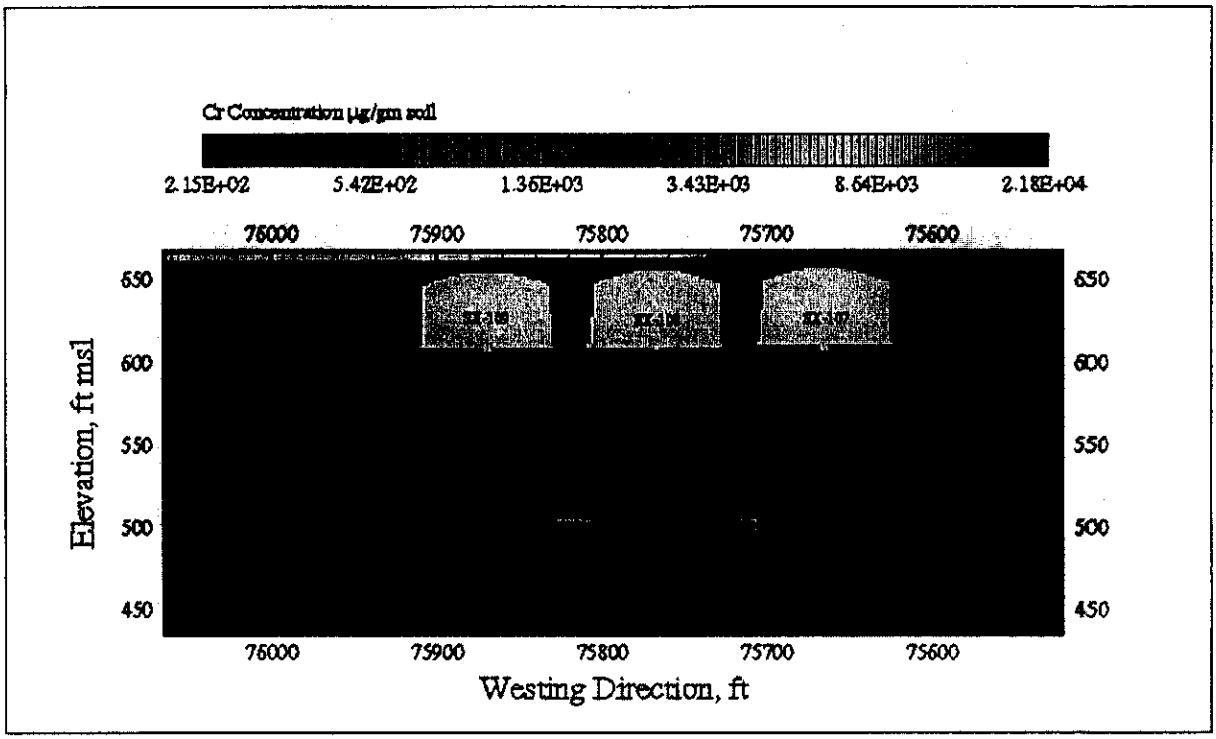


Figure E2.28. Initial NO_3 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

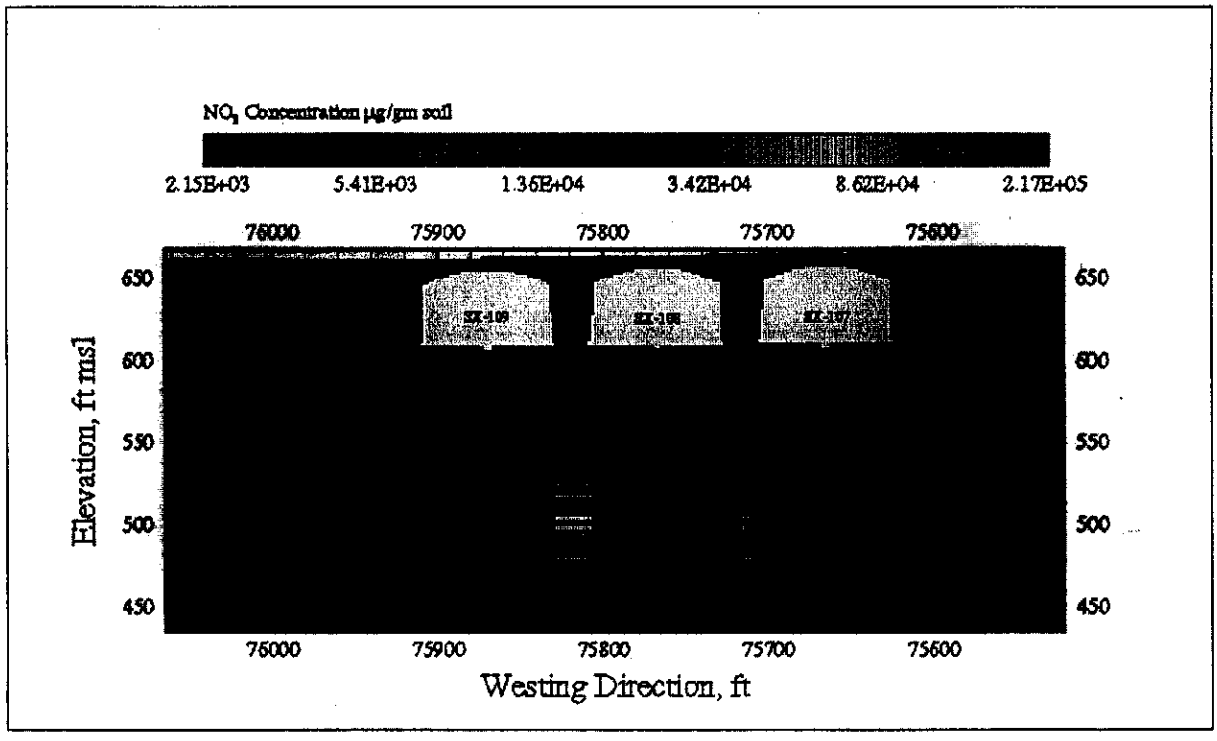


Figure E2.29. Initial Cs-137 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

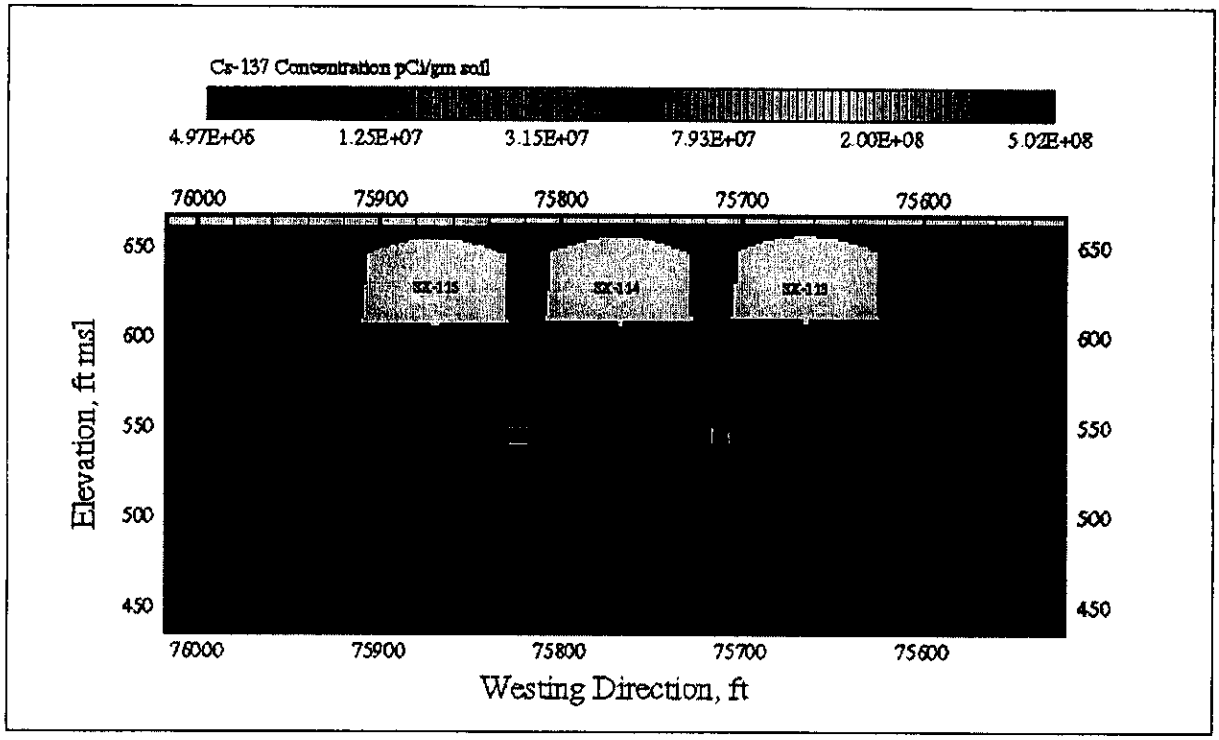


Figure E2.30. Initial Tc-99 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

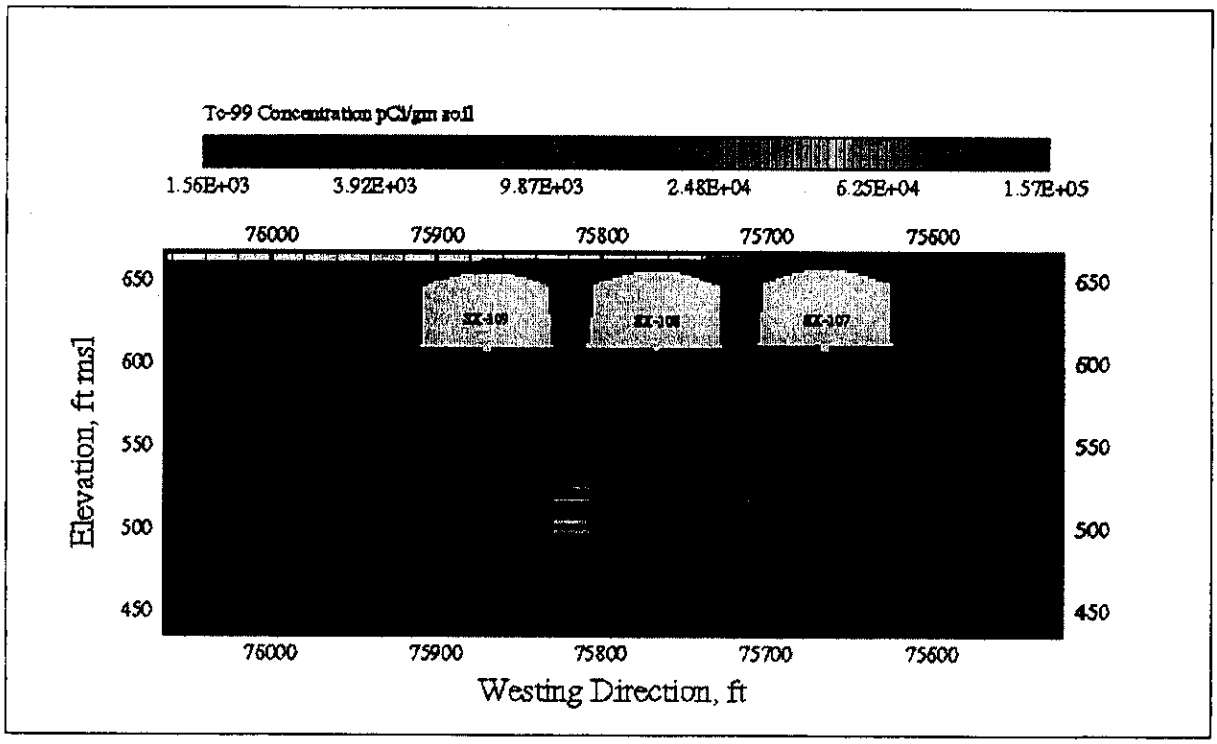


Figure E2.31. Initial Cr Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

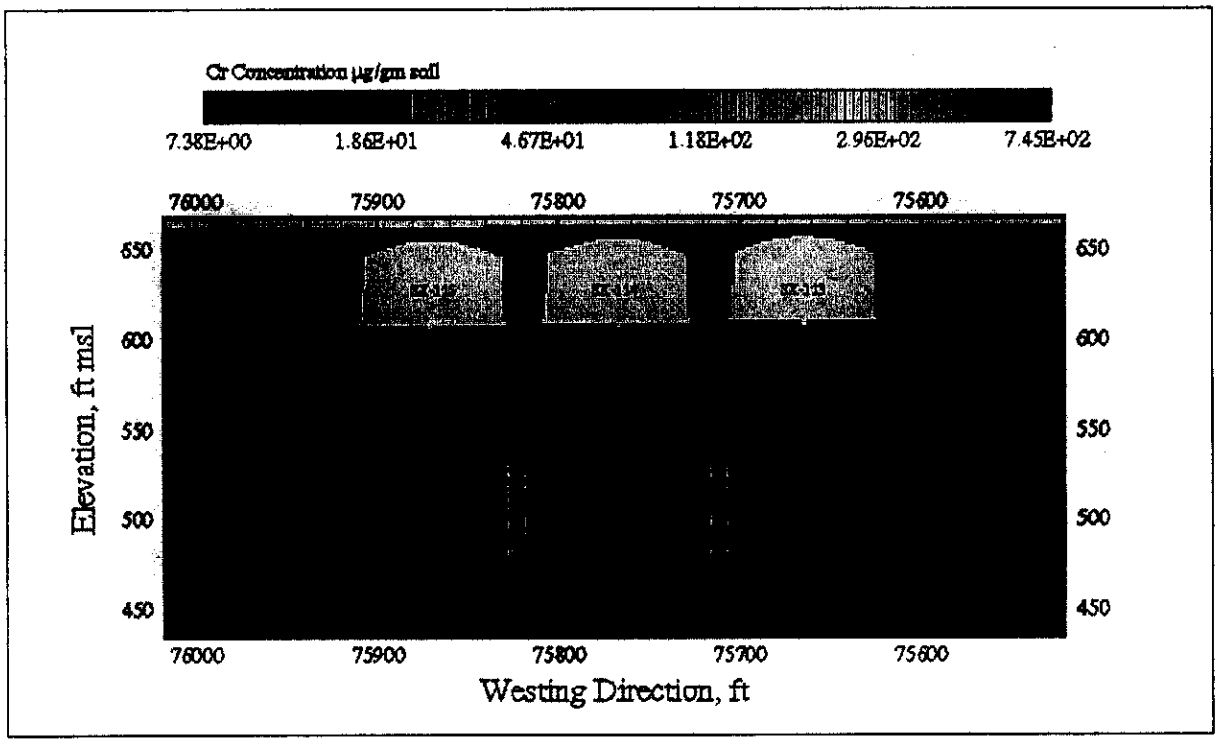


Figure E2.32. Initial NO_3 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

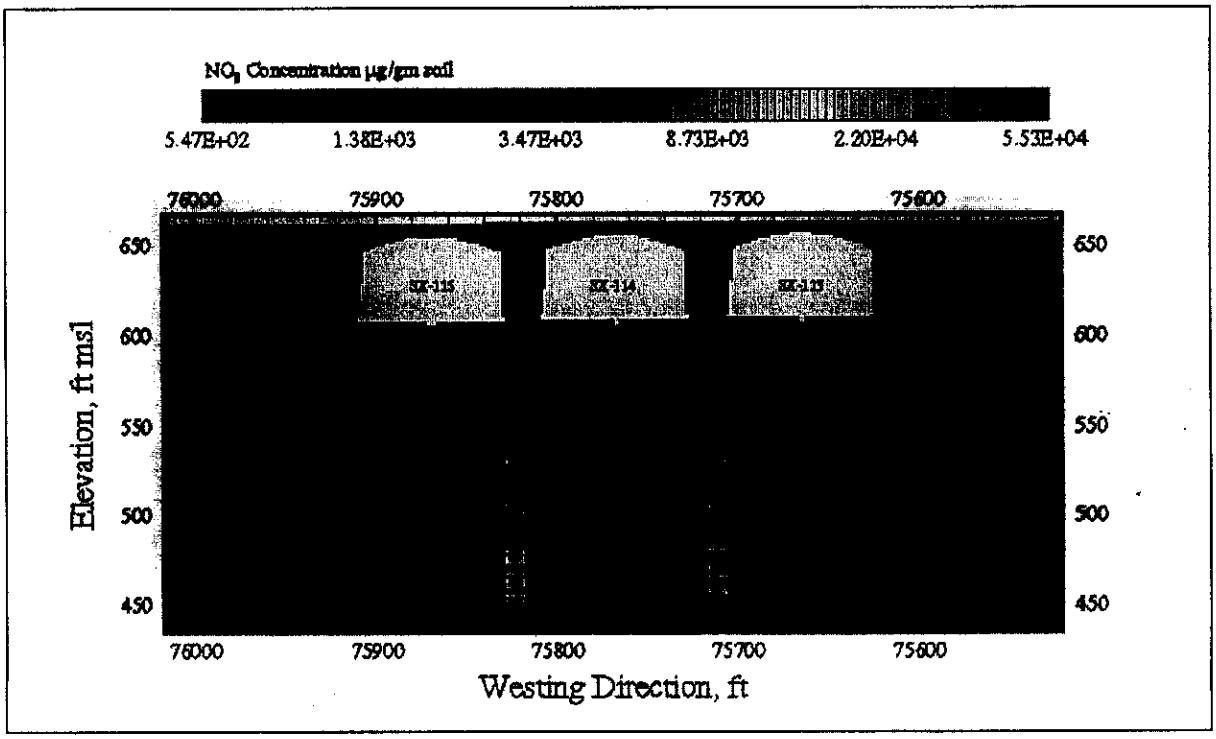


Figure E2.33. Initial Cs-137 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section S-CC' (S-104, -105, -106)

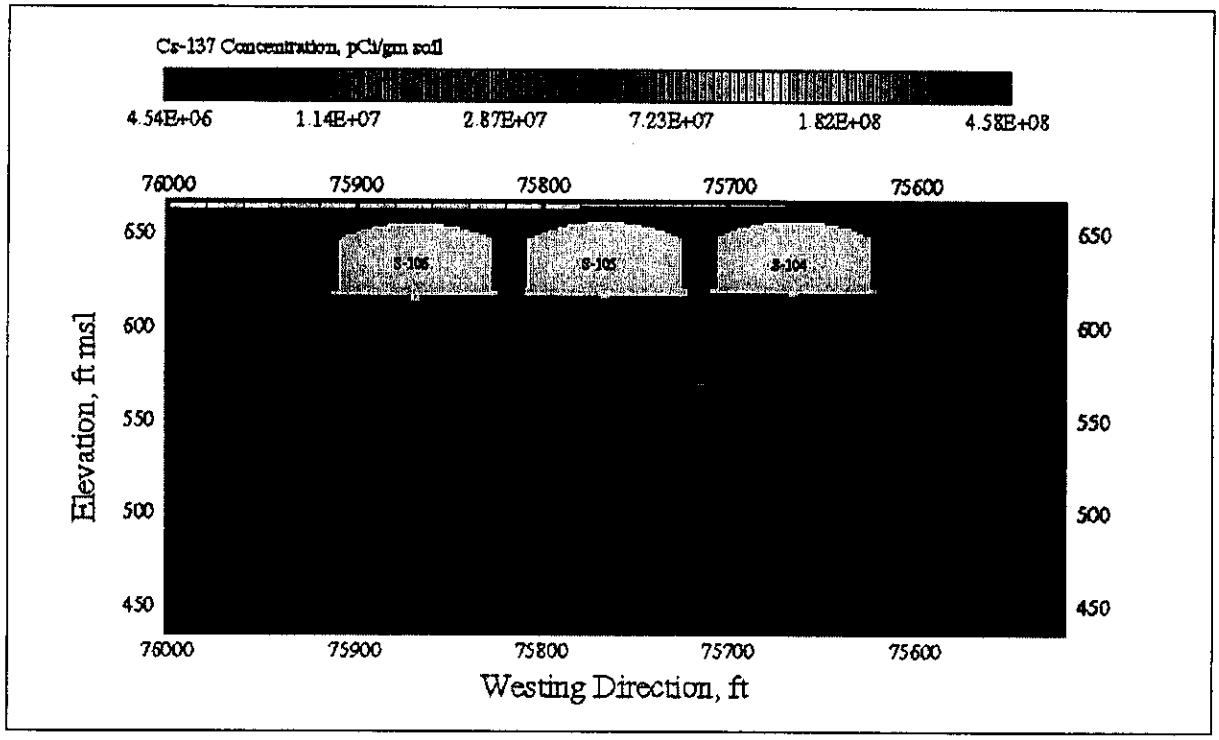


Figure E2.34. Initial Tc-99 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section S-CC' (S-104, -105, -106)

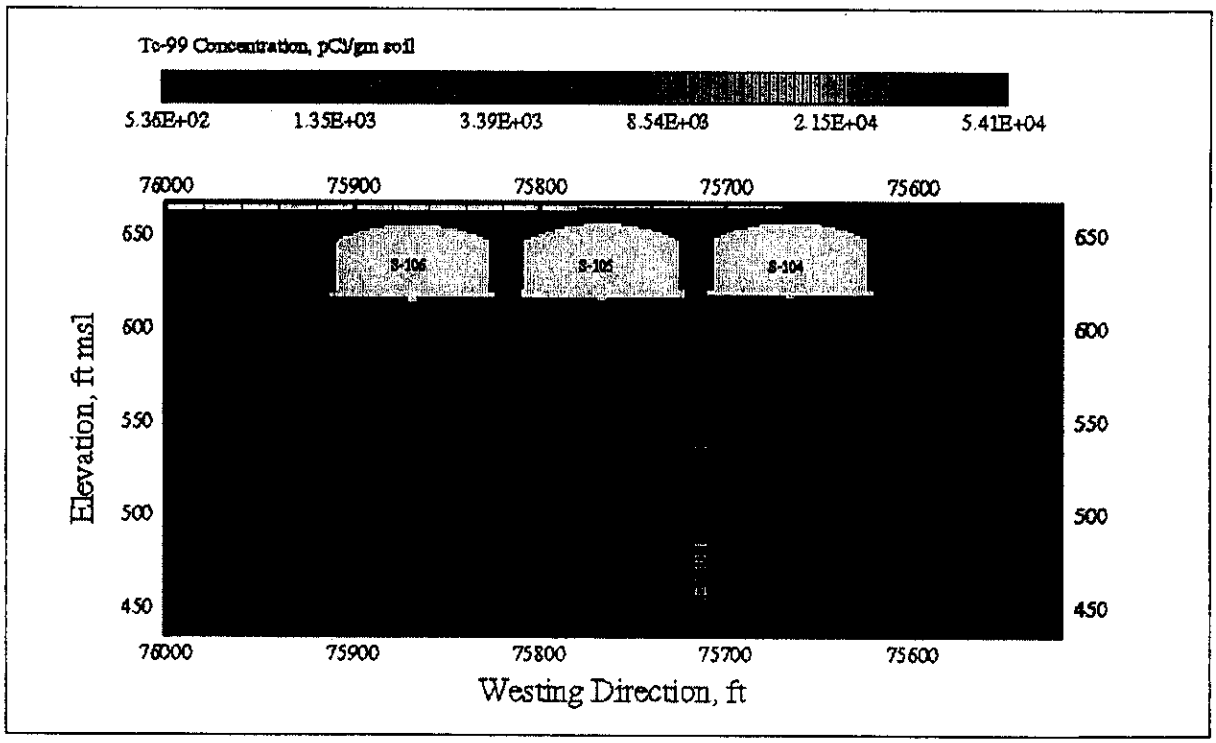


Figure E2.35. Initial Cr Aqueous-Phase Concentration, Displaced Distribution, Cross-Section S-CC' (S-104, -105, -106)

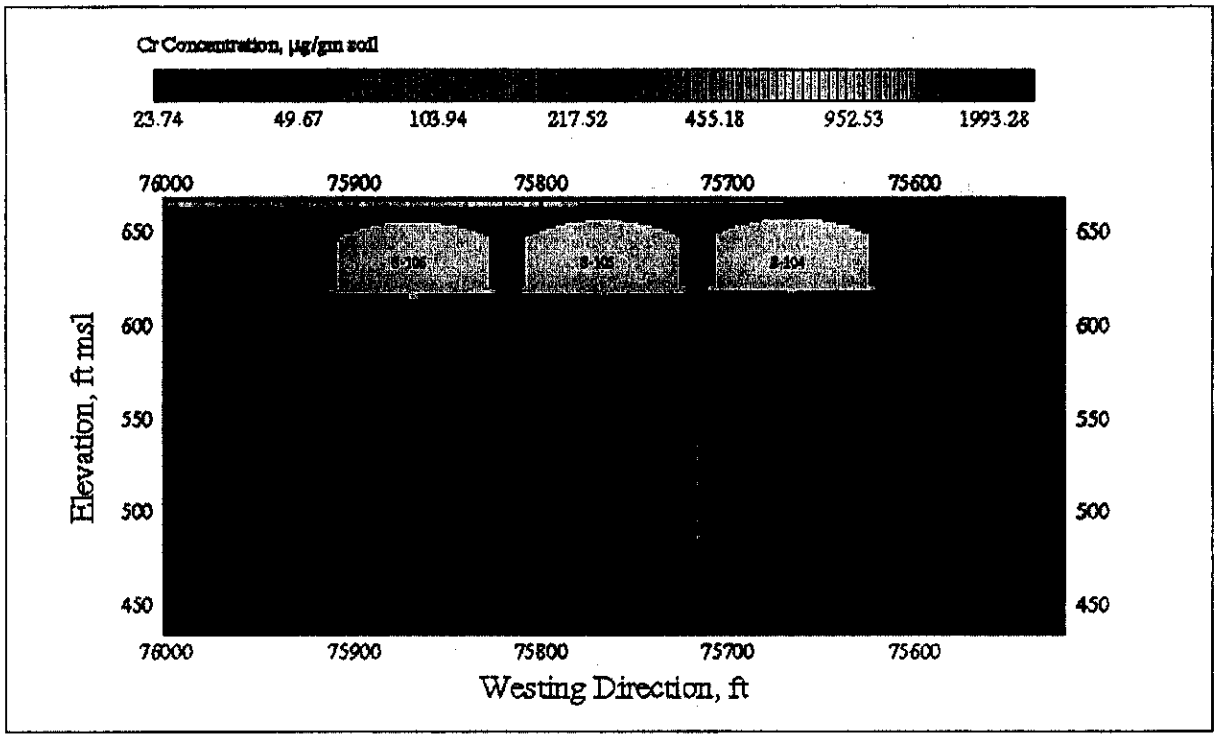
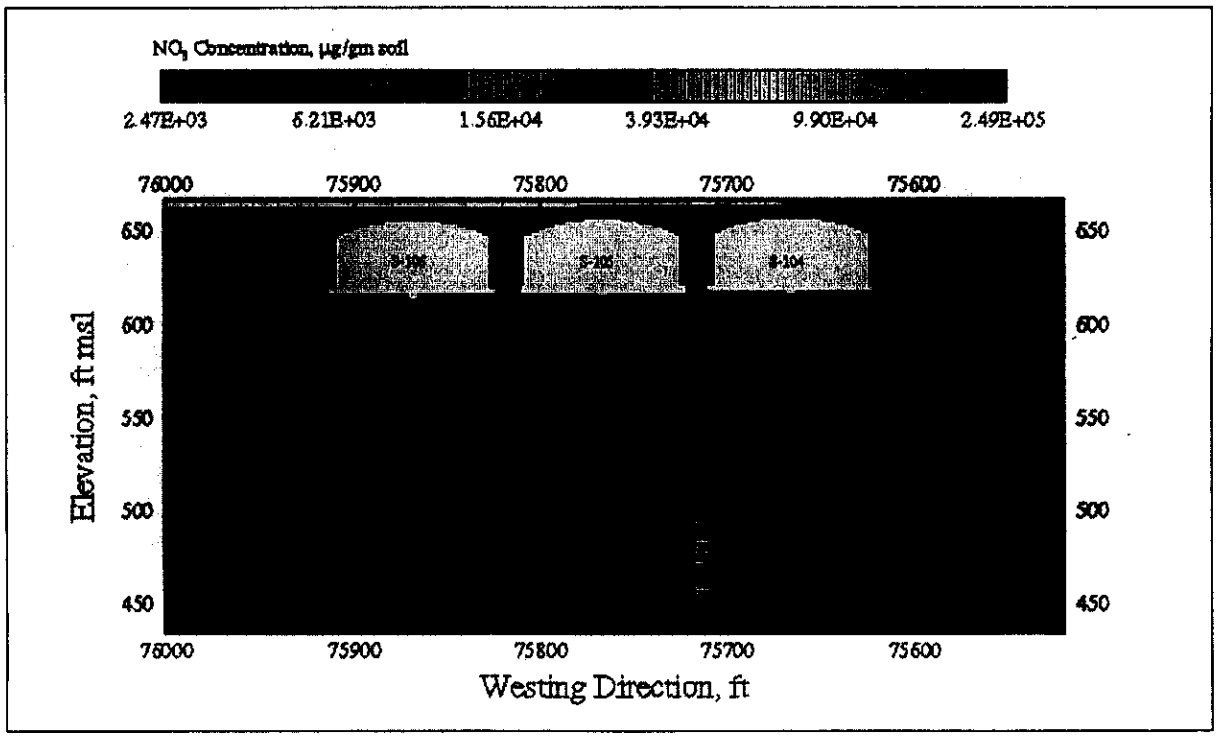


Figure E2.36. Initial NO_3 Aqueous-Phase Concentration, Displaced Distribution, Cross-Section S-CC' (S-104, -105, -106)



E2.4.0 ALTERNATE INITIAL INVENTORY DISTRIBUTIONS

Color-scaled images of the alternate initial inventory distributions for the contaminant species (i.e., cesium-137, technetium-99, chromium, and nitrate) are shown in Figures E2.37 through E2.48 for cross-sections SX-DD', SX-FF', and S-CC'. The alternate inventory distributions only conserve the integrated mass records for each elevation bin. The concentration is computed based on distribution radius and integrated mass for the elevation bin. Inventories are assumed to be distributed at each grid elevation as a circular disk.

Figure E2.37. Initial Cs-137 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

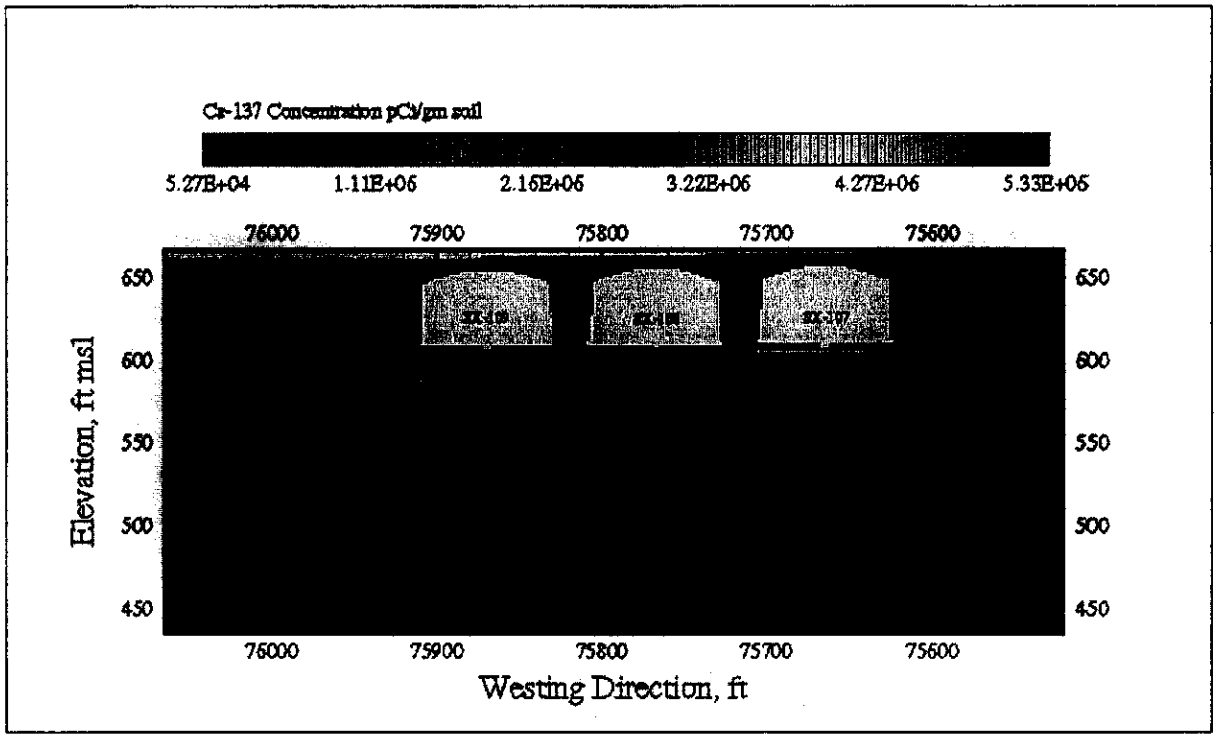


Figure E2.38. Initial Tc-99 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

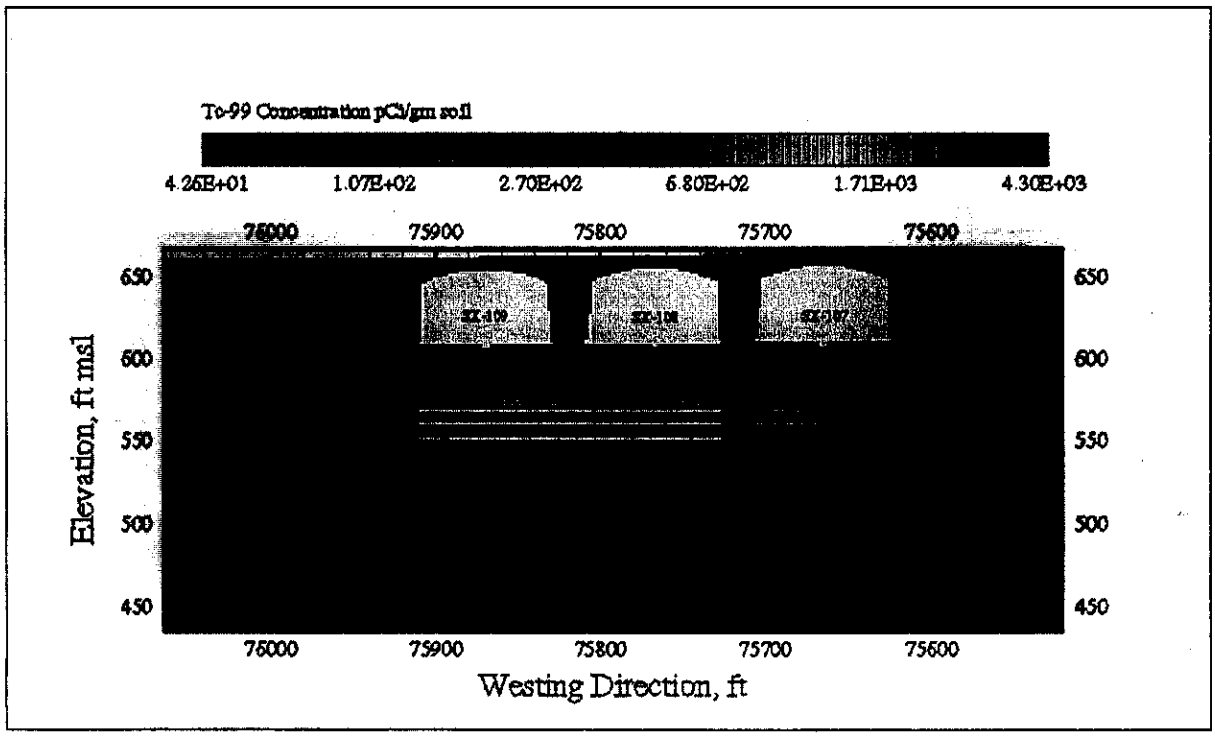


Figure E2.39. Initial Cr Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

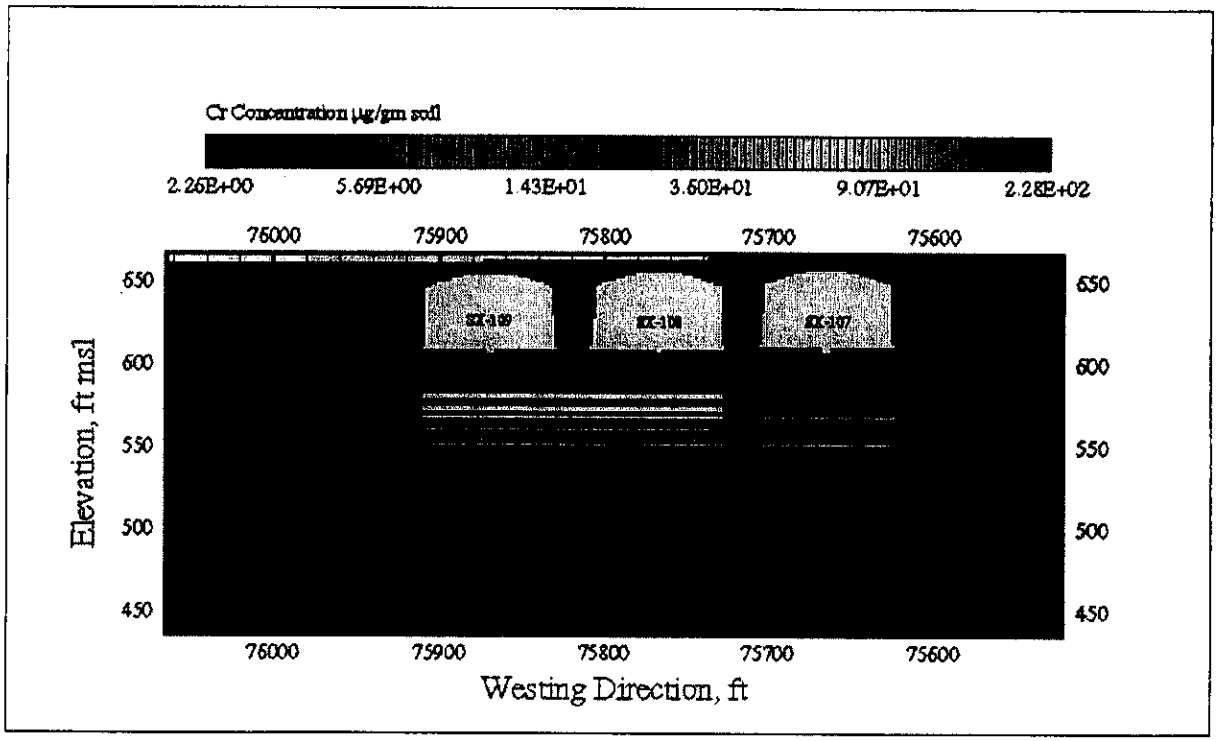


Figure E2.40. Initial NO_3 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-DD' (SX-107, -108, -109)

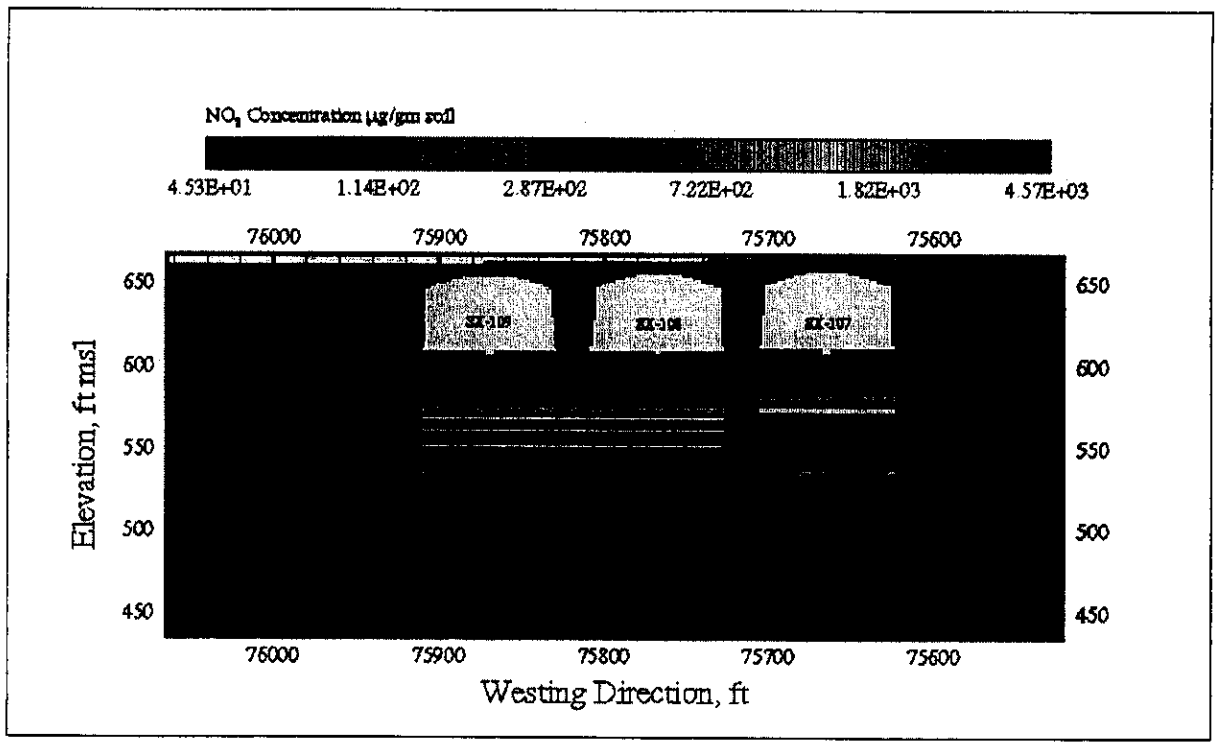


Figure E2.41. Initial Cs-137 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

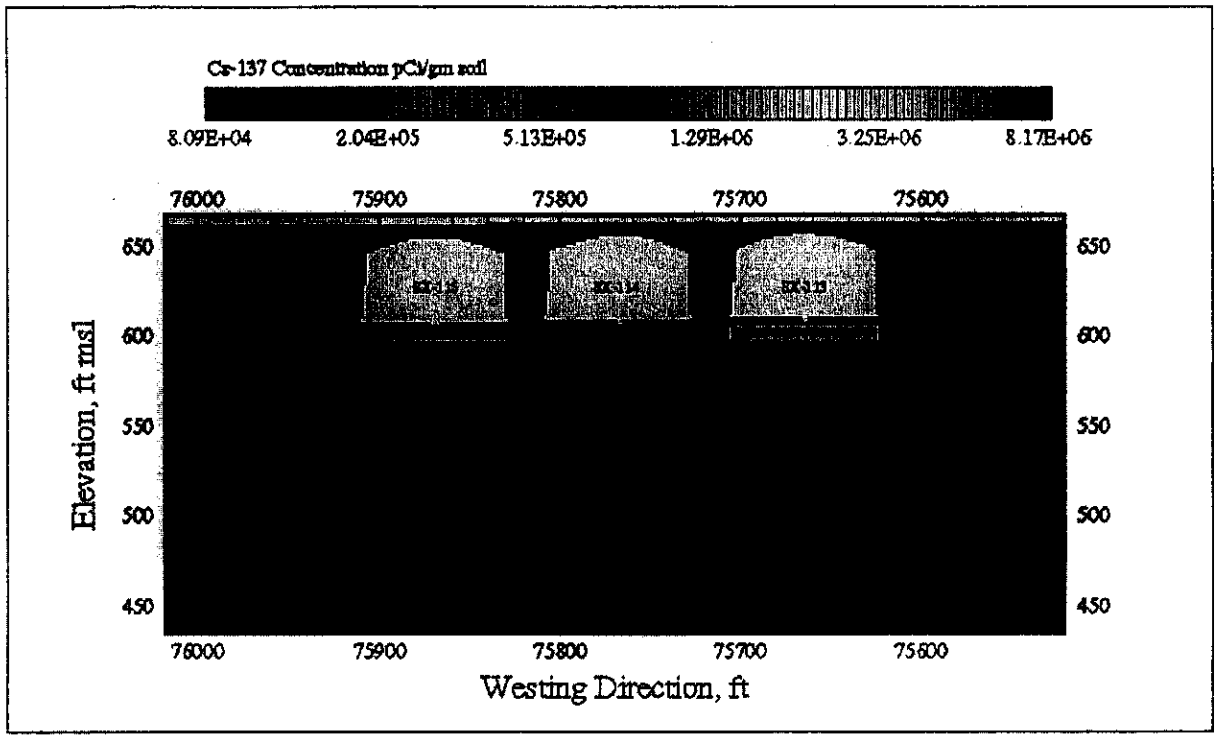


Figure E2.42. Initial Tc-99 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

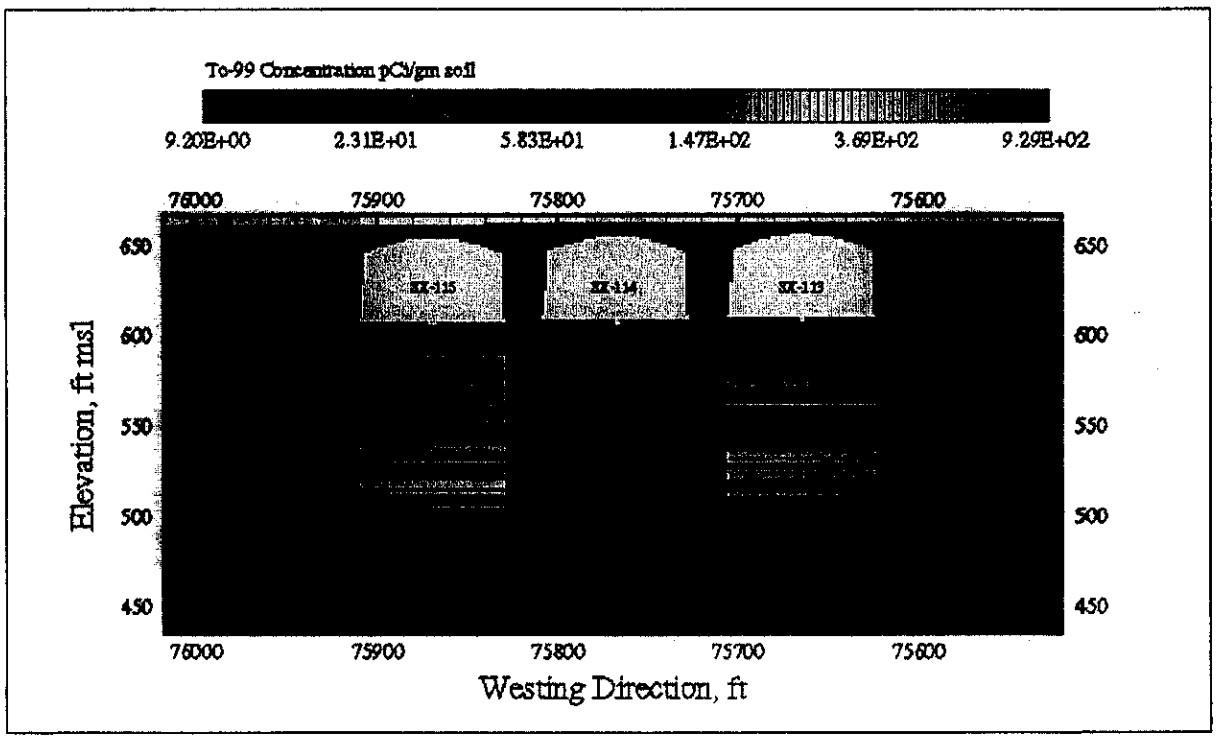


Figure E2.43. Initial Cr Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

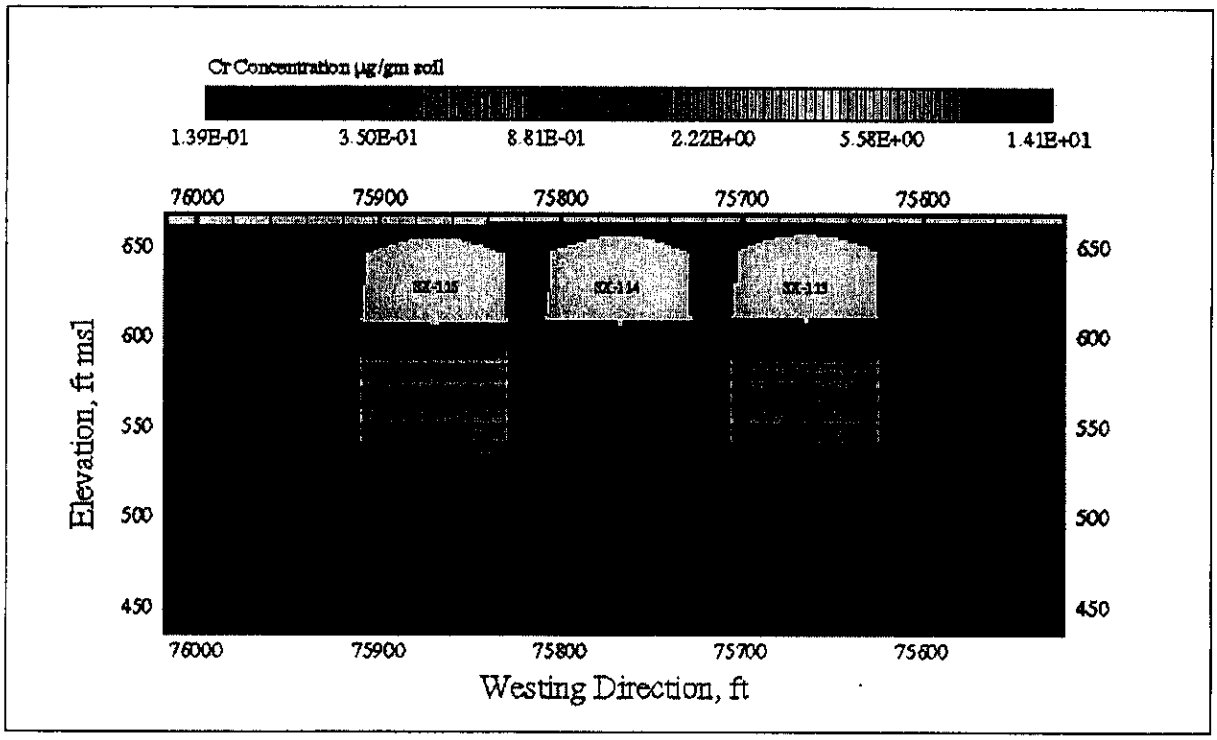


Figure E2.44. Initial NO_3 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section SX-FF' (SX-113, -114, -115)

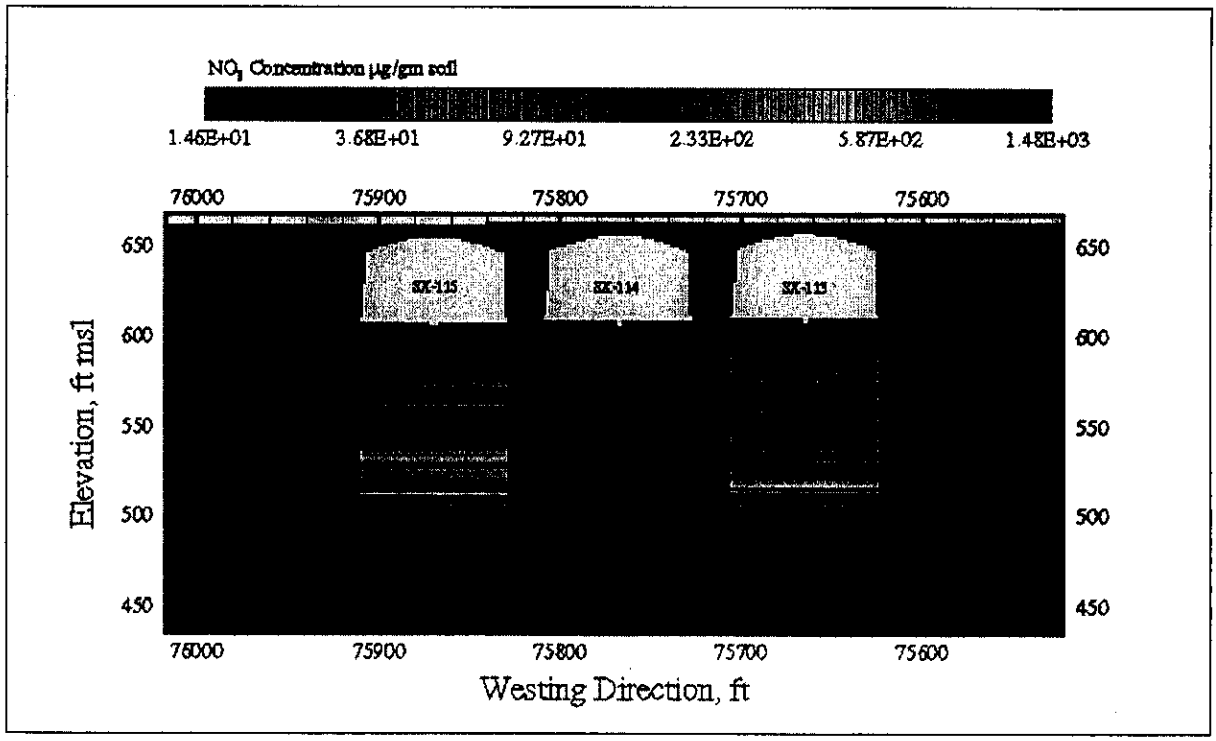


Figure E2.45. Initial Cs-137 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section S-CC' (S-104, -105, -106)

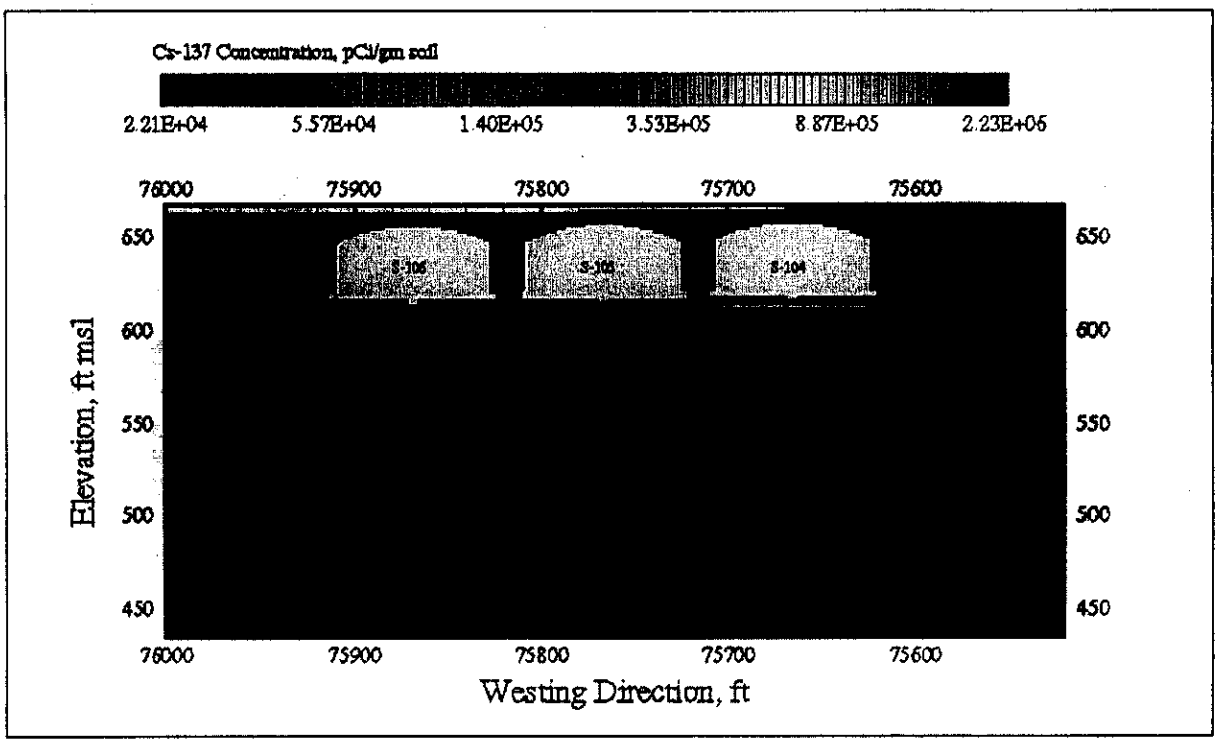


Figure E2.46. Initial Tc-99 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section S-CC' (S-104, -105, -106)

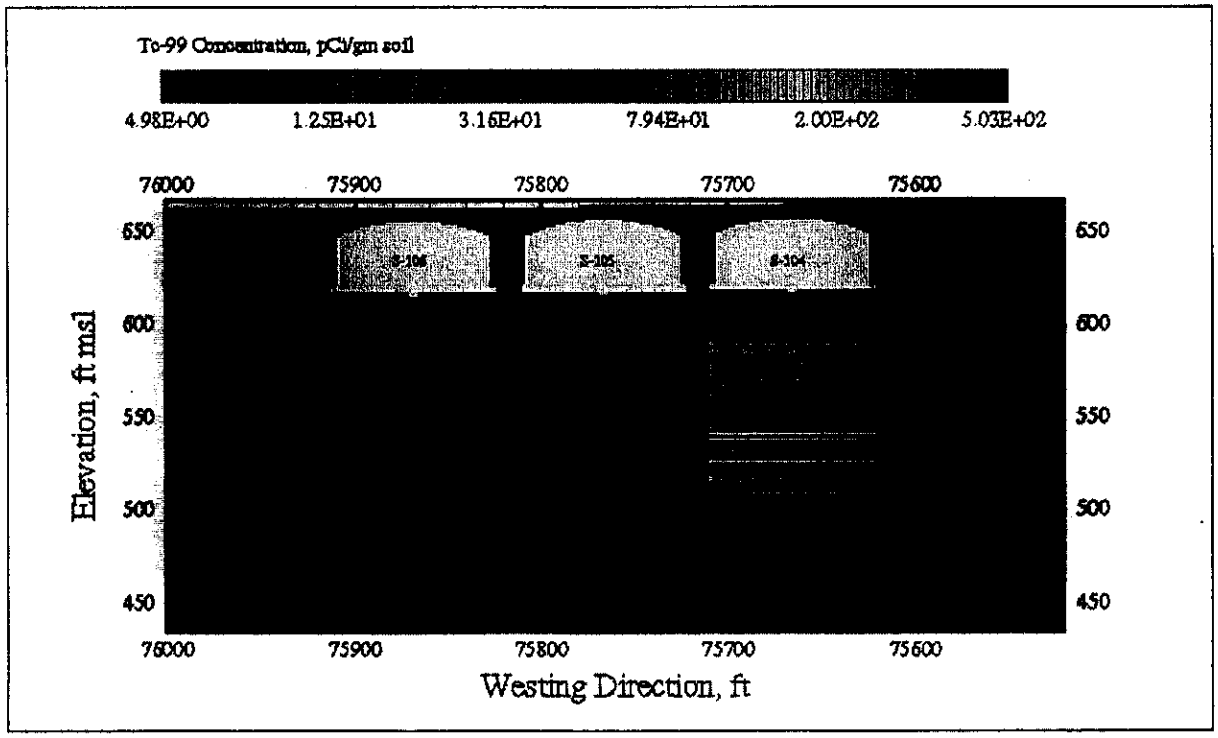


Figure E2.47. Initial Cr Aqueous-Phase Concentration, Alternate Distribution, Cross-Section S-CC' (S-104, -105, -106)

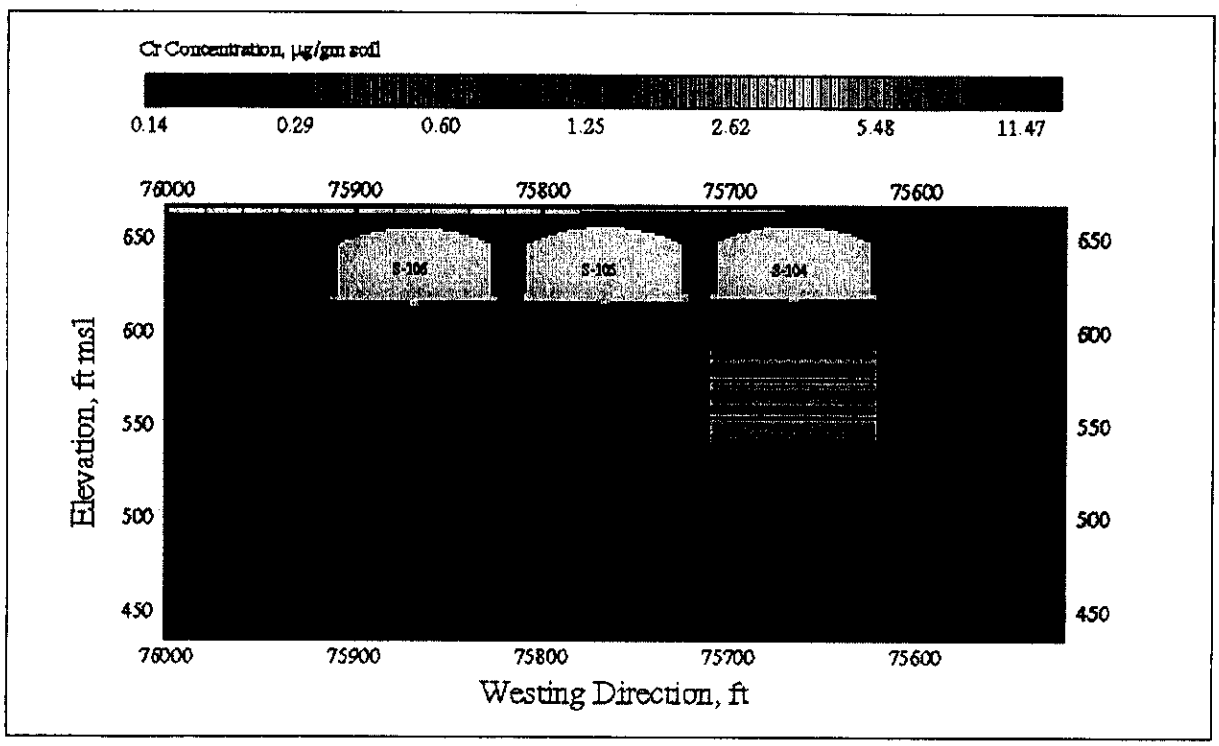
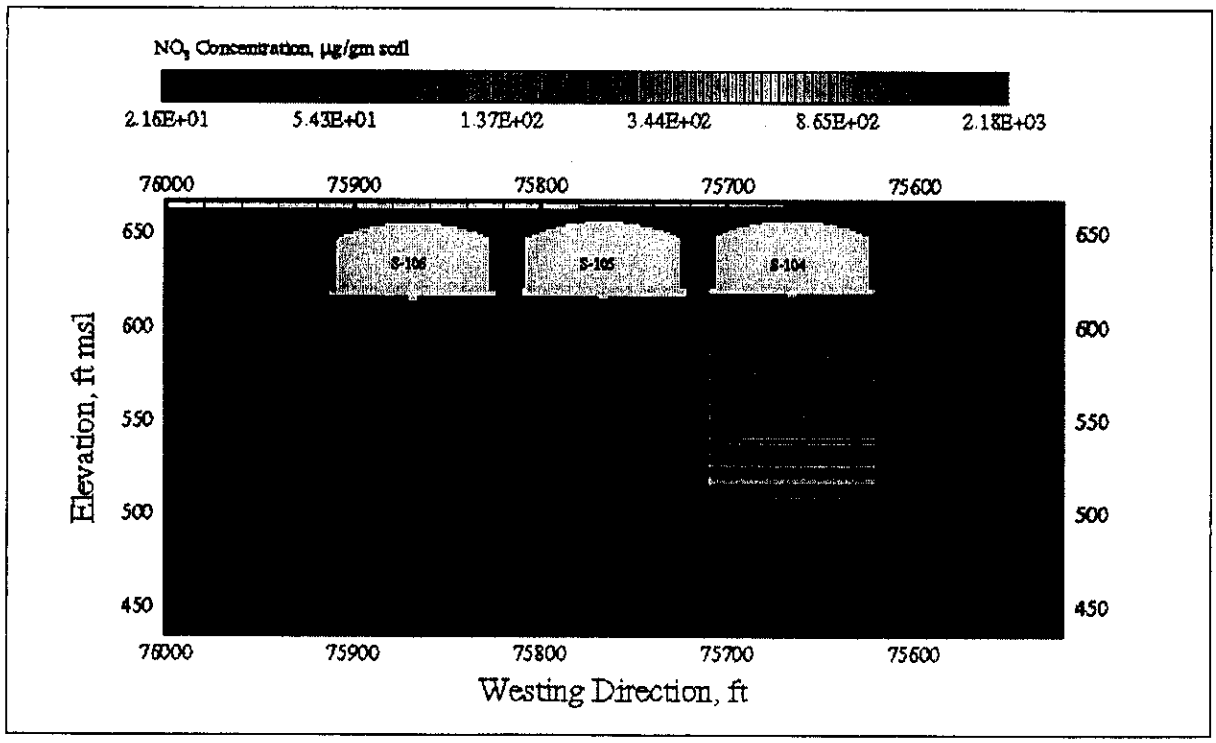


Figure E2.48. Initial NO_3 Aqueous-Phase Concentration, Alternate Distribution, Cross-Section S-CC' (S-104, -105, -106)



ATTACHMENT E3

VADOSE ZONE AND UNCONFINED AQUIFER MODELING RESULTS

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E3.1.0 CASE 1: BASE CASE (NO ACTION ALTERNATIVE)

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only, no water-line leak, no interim barrier and a closure barrier by the year 2040.

Figure E3.1. Case 1 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

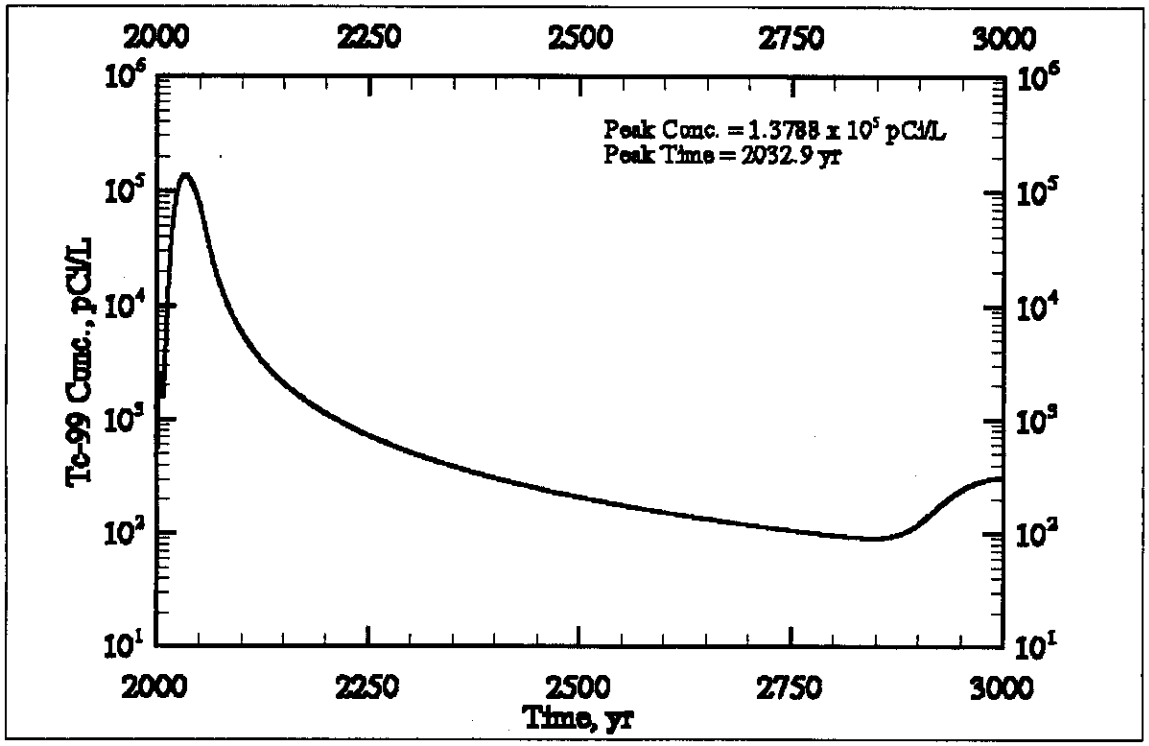


Figure E3.2. Case 1 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

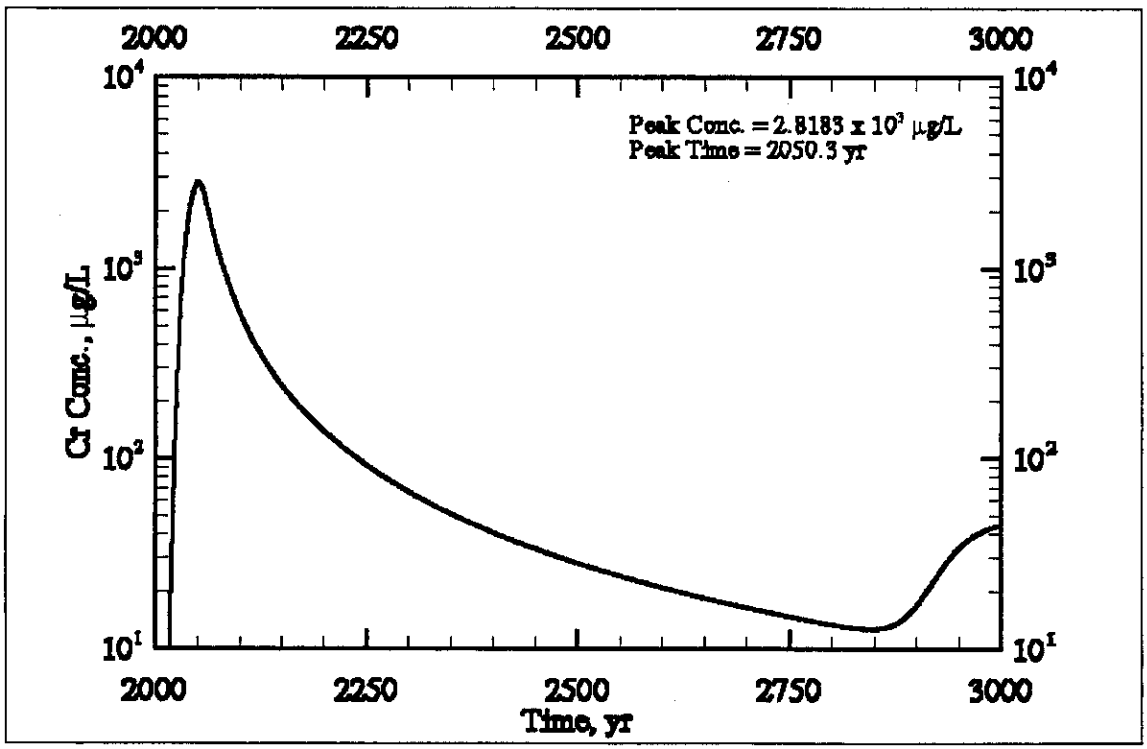


Figure E3.3. Case 1 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

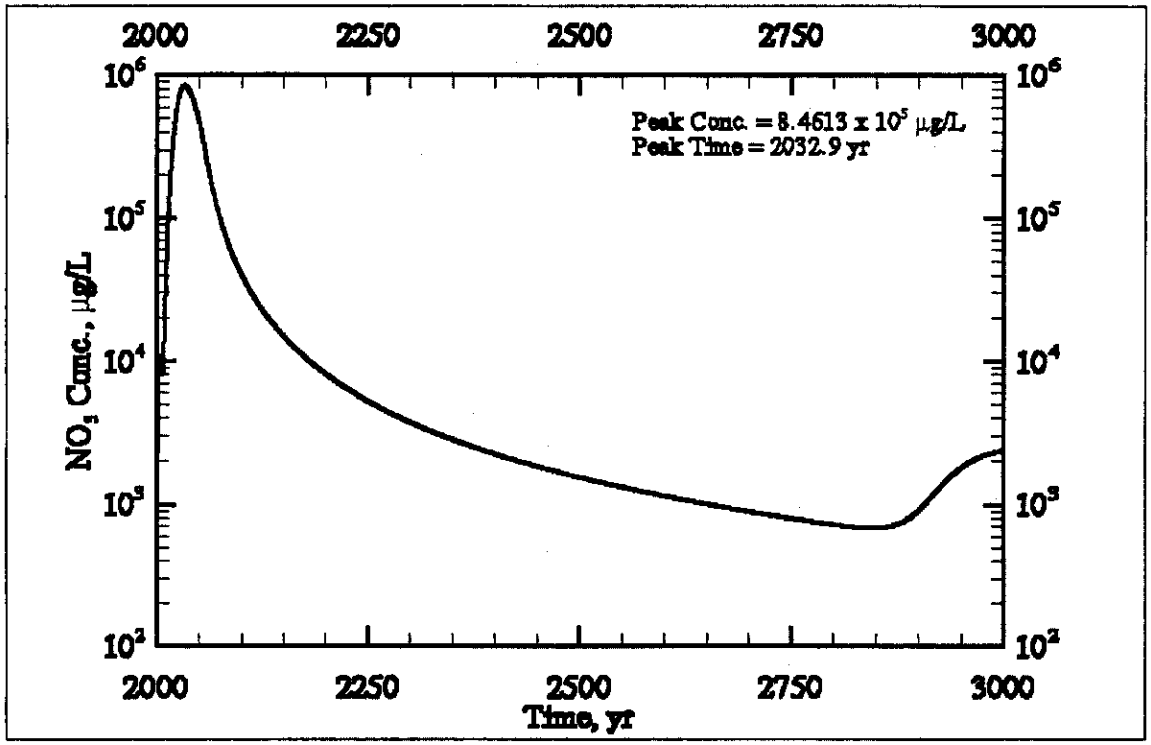


Figure E3.4. Case 1 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

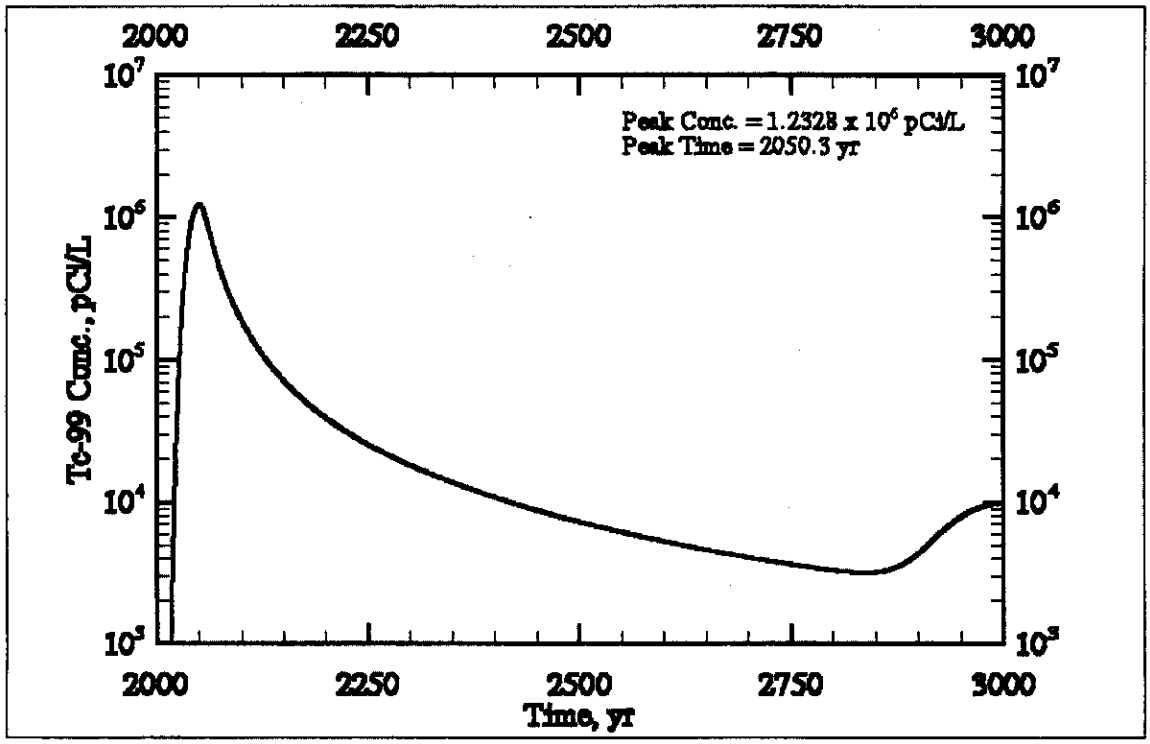


Figure E3.5. Case 1 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

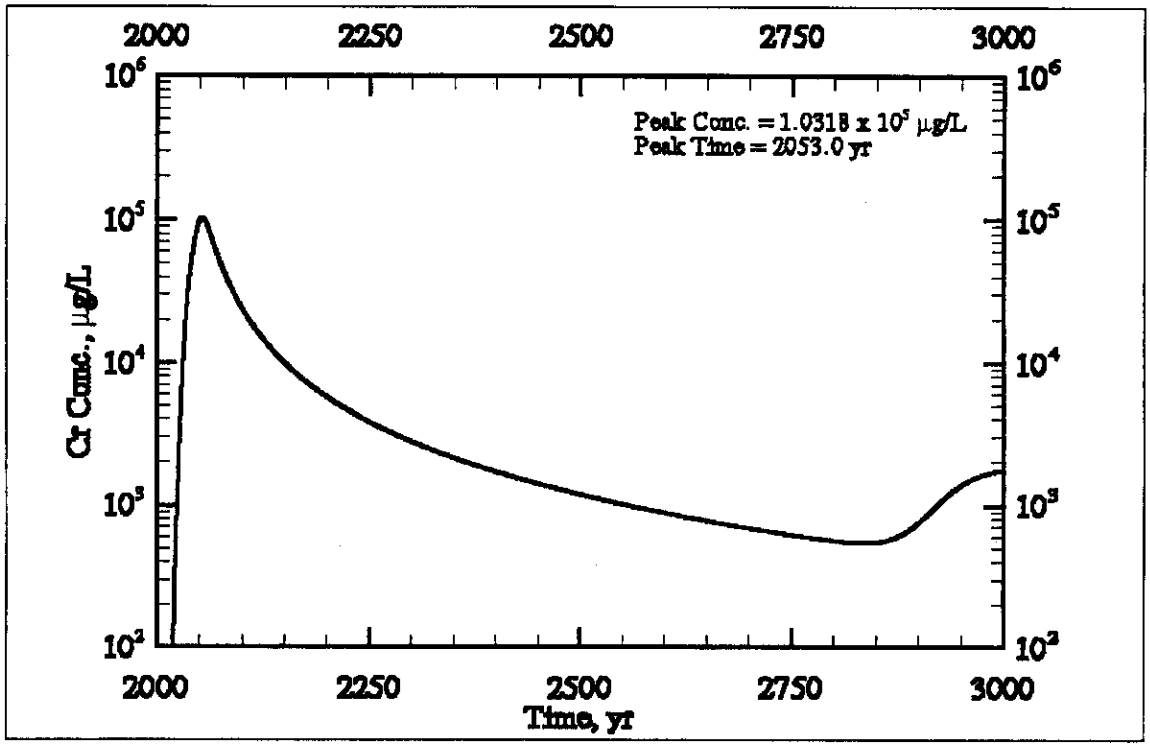


Figure E3.6. Case 1 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

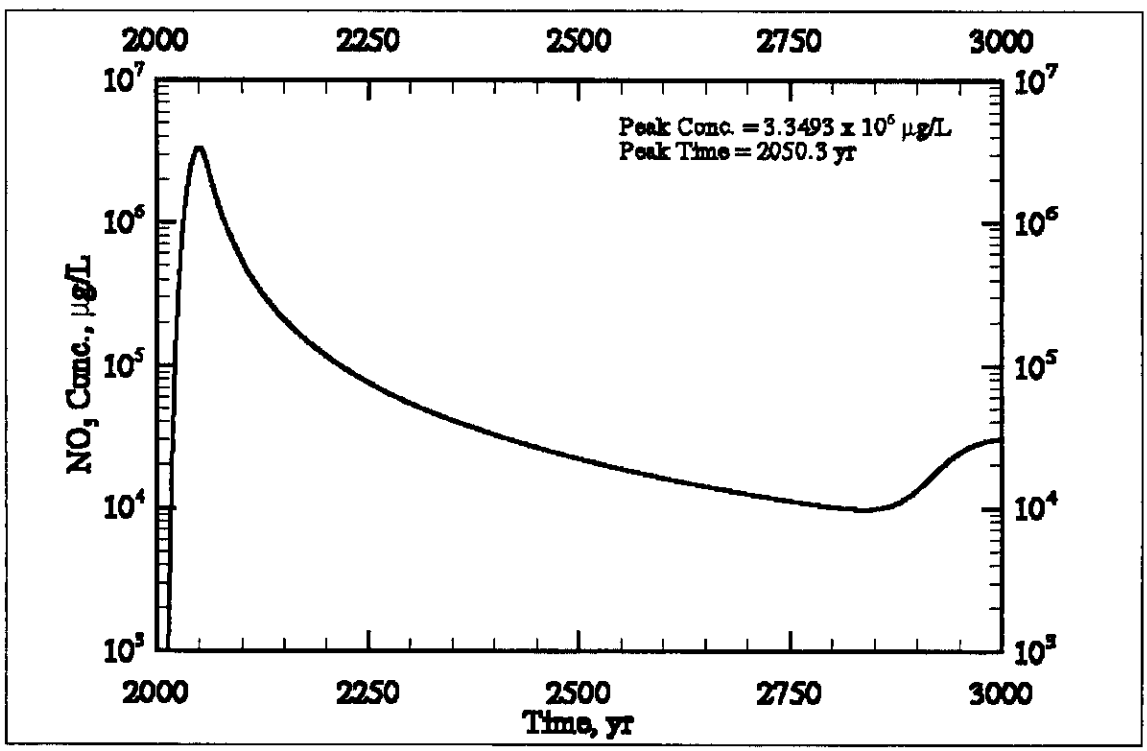


Figure E3.7. Case 1 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

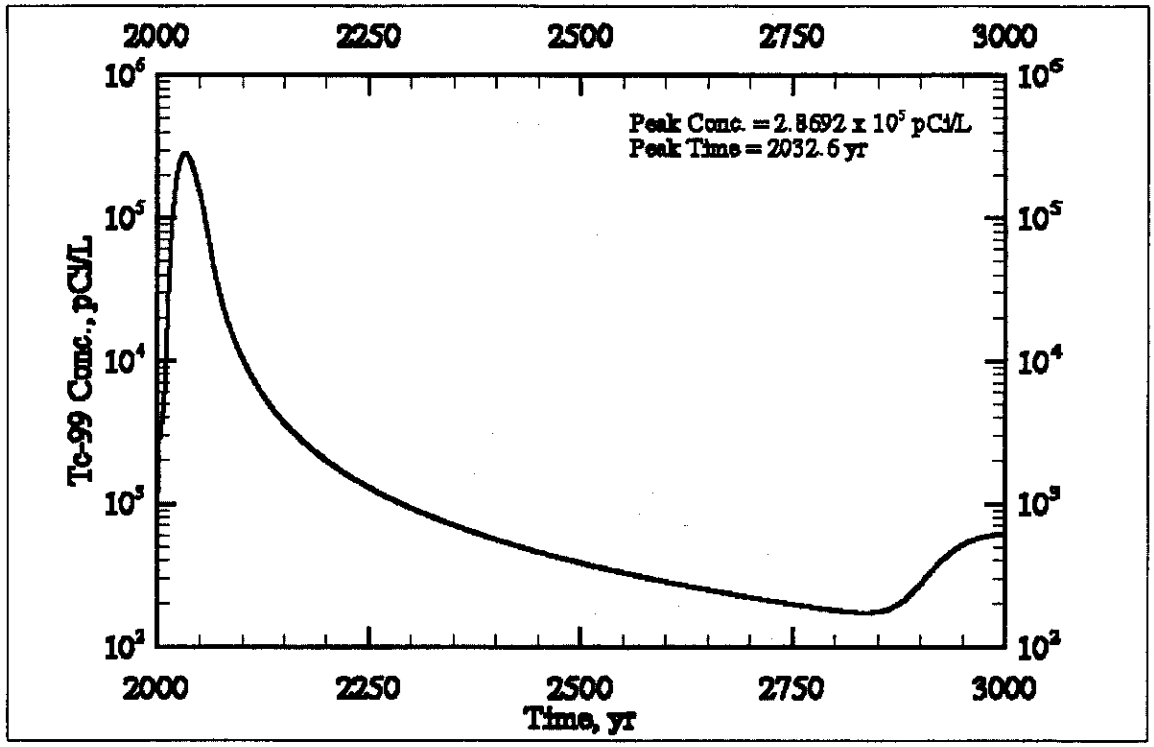


Figure E3.8. Case 1 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

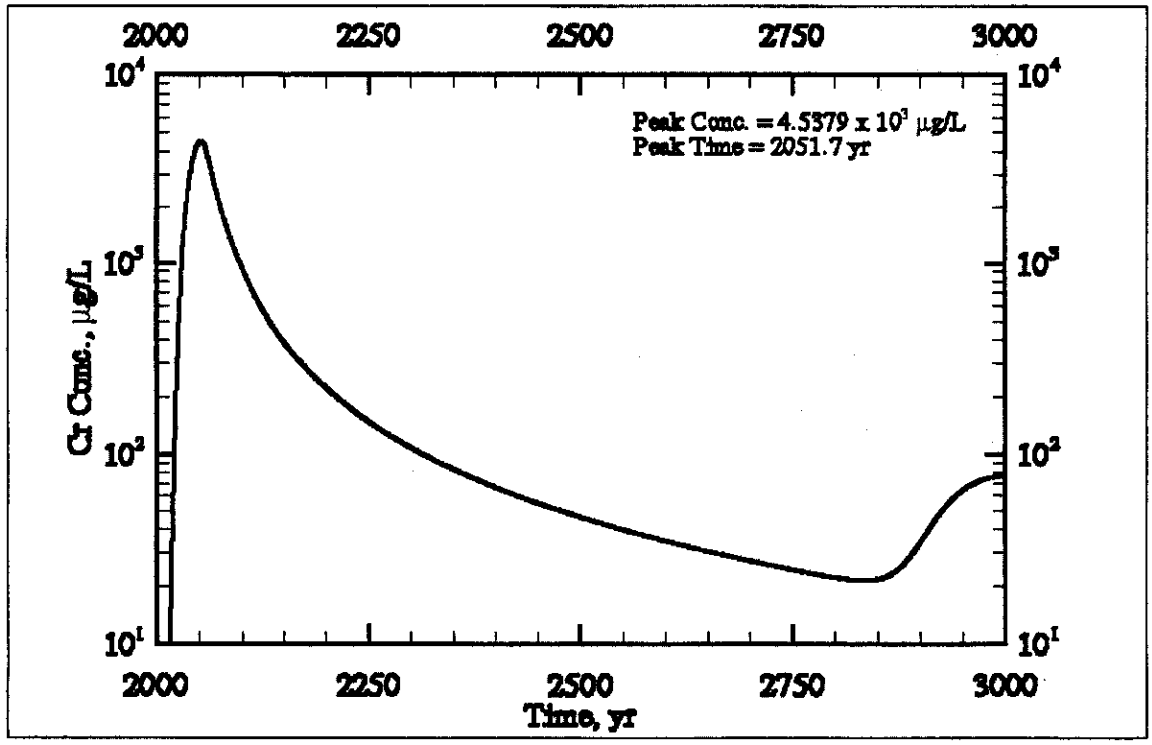


Figure E3.9. Case 1 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

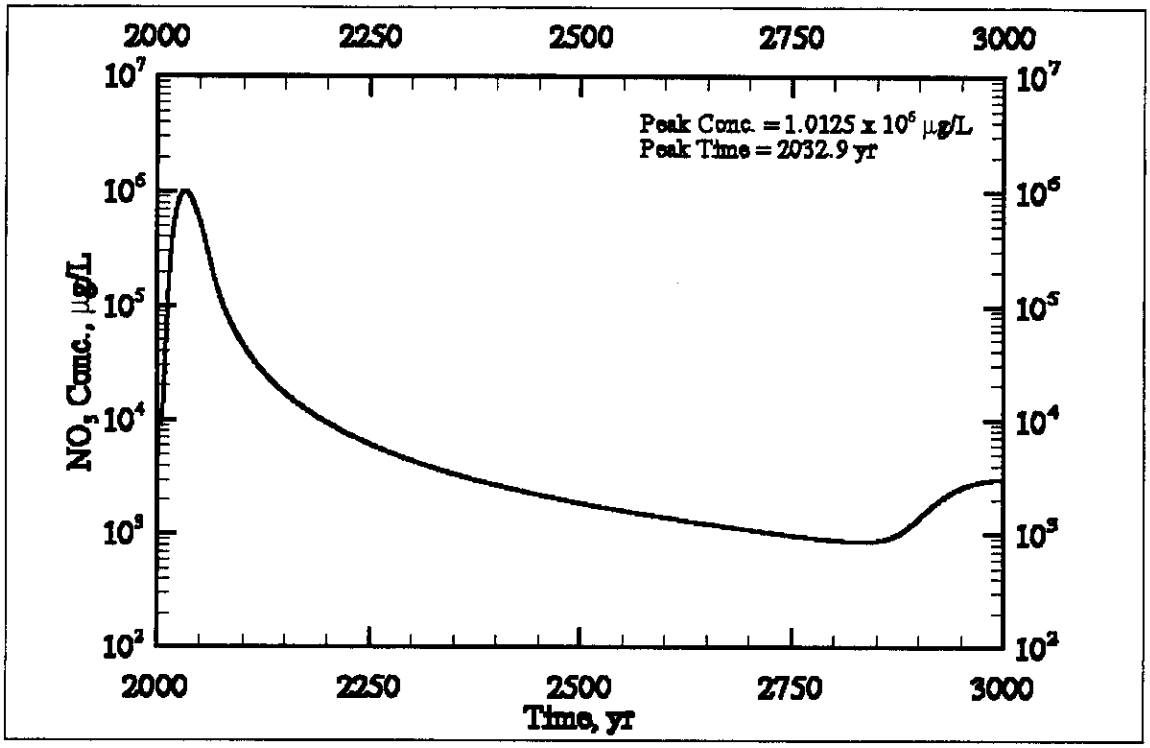


Figure E3.10. Case 1 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

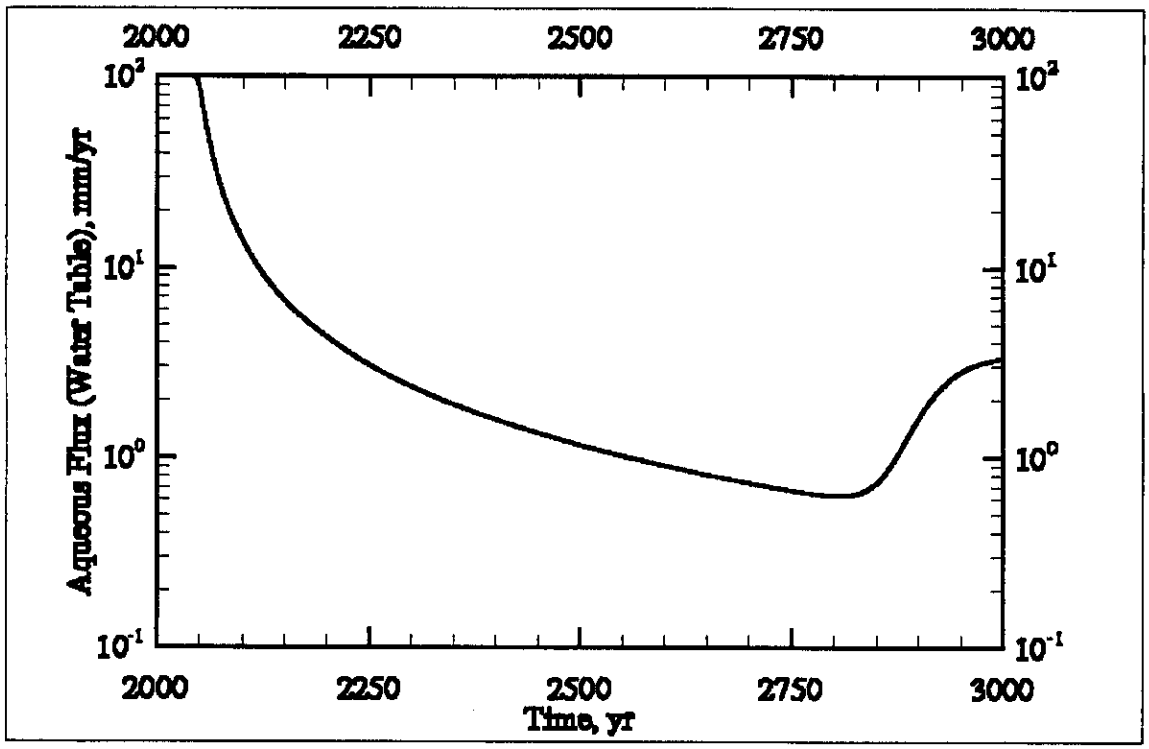


Figure E3.11. Case 1 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

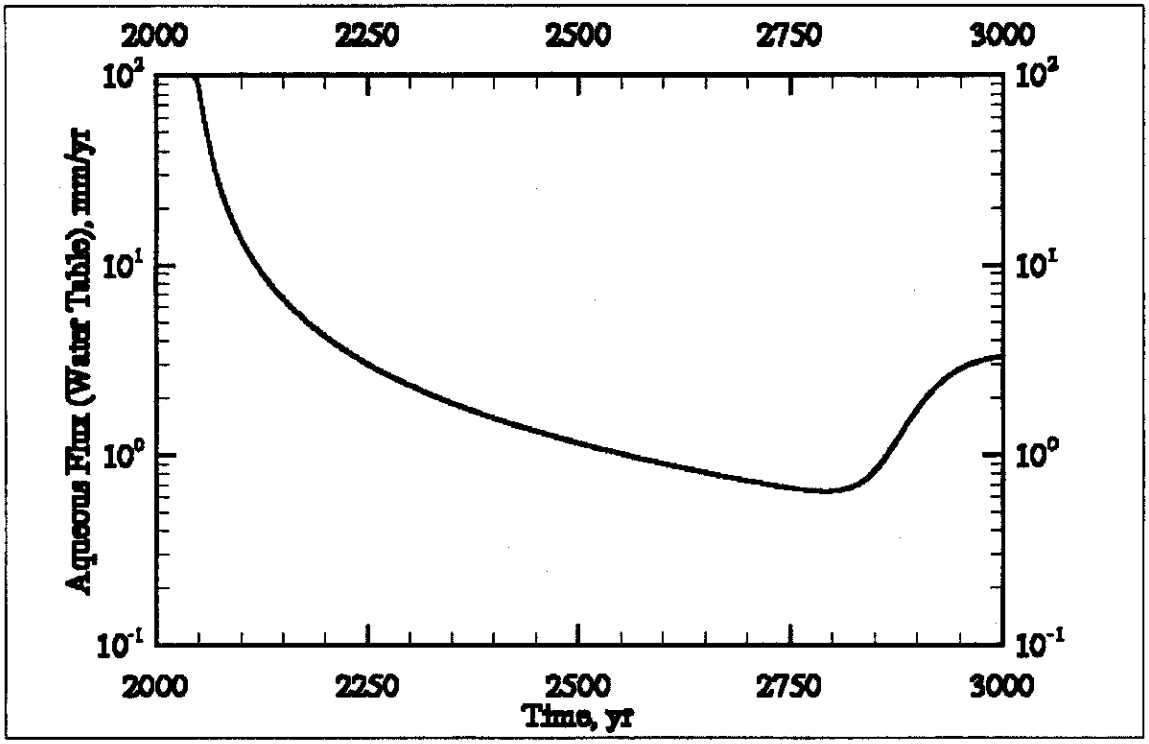


Figure E3.12. Case 1 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

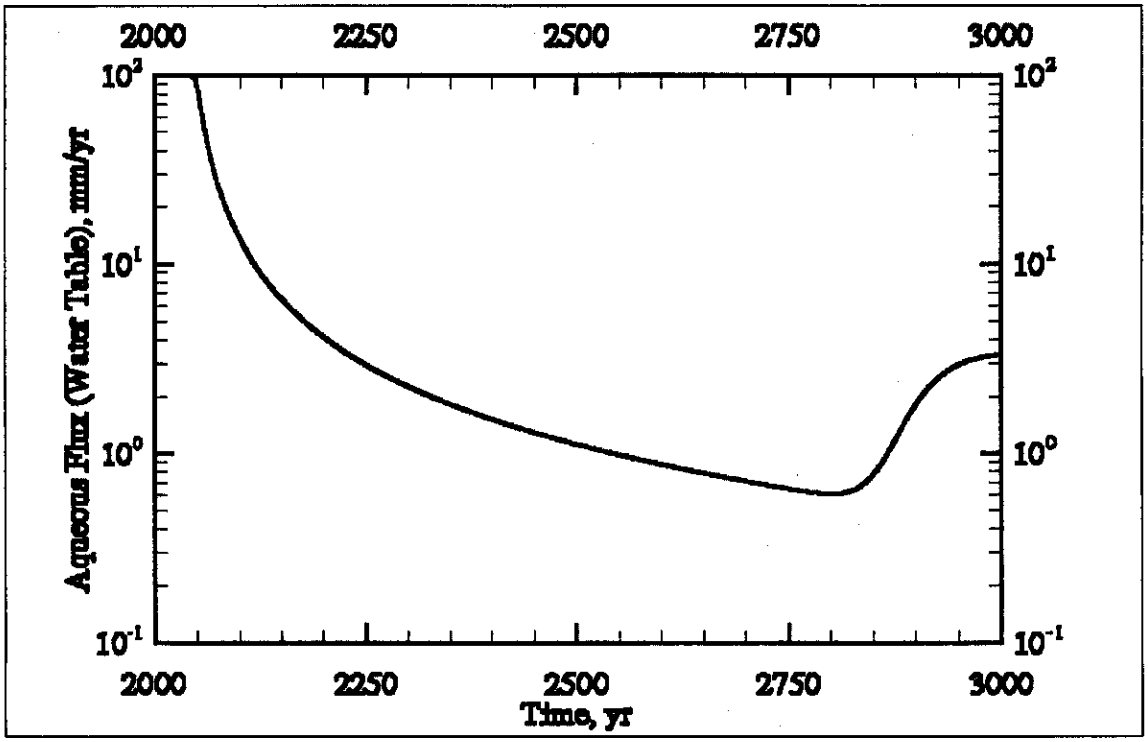


Figure E3.13. Case 1 Area-Weighted Average Tc-99 Concentration and Dose versus Time at Compliance Points

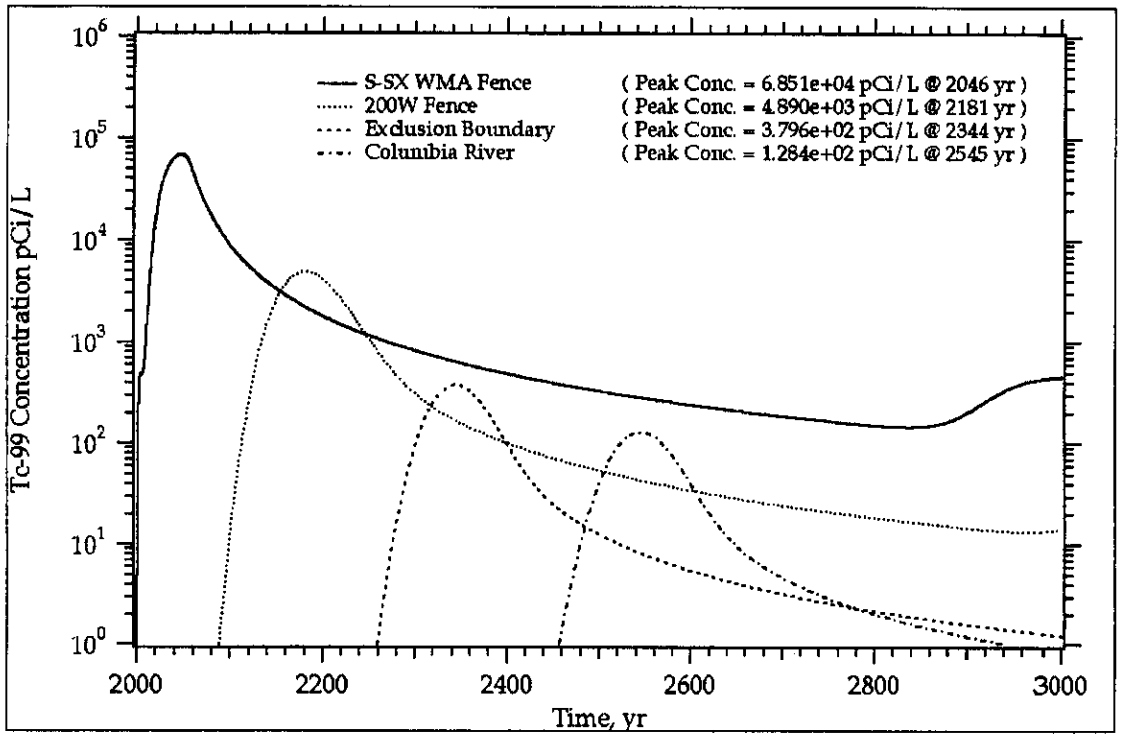


Figure E3.14. Case 1 Area-Weighted Average Cr Concentration versus Time at Compliance Points

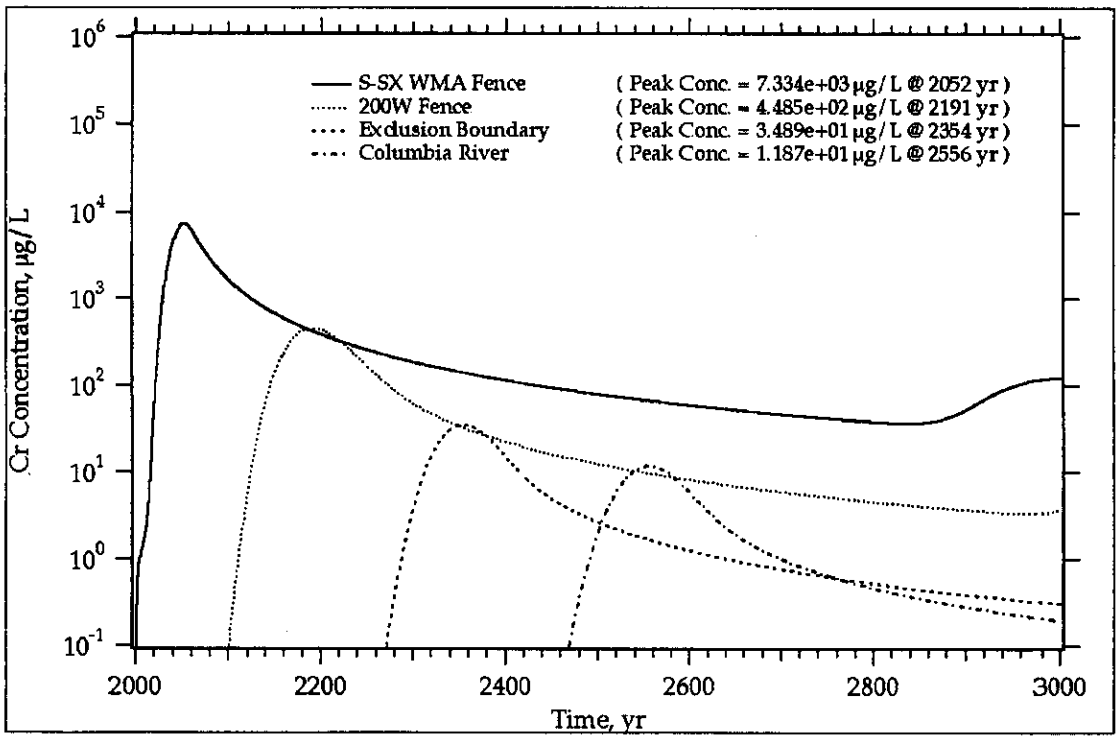
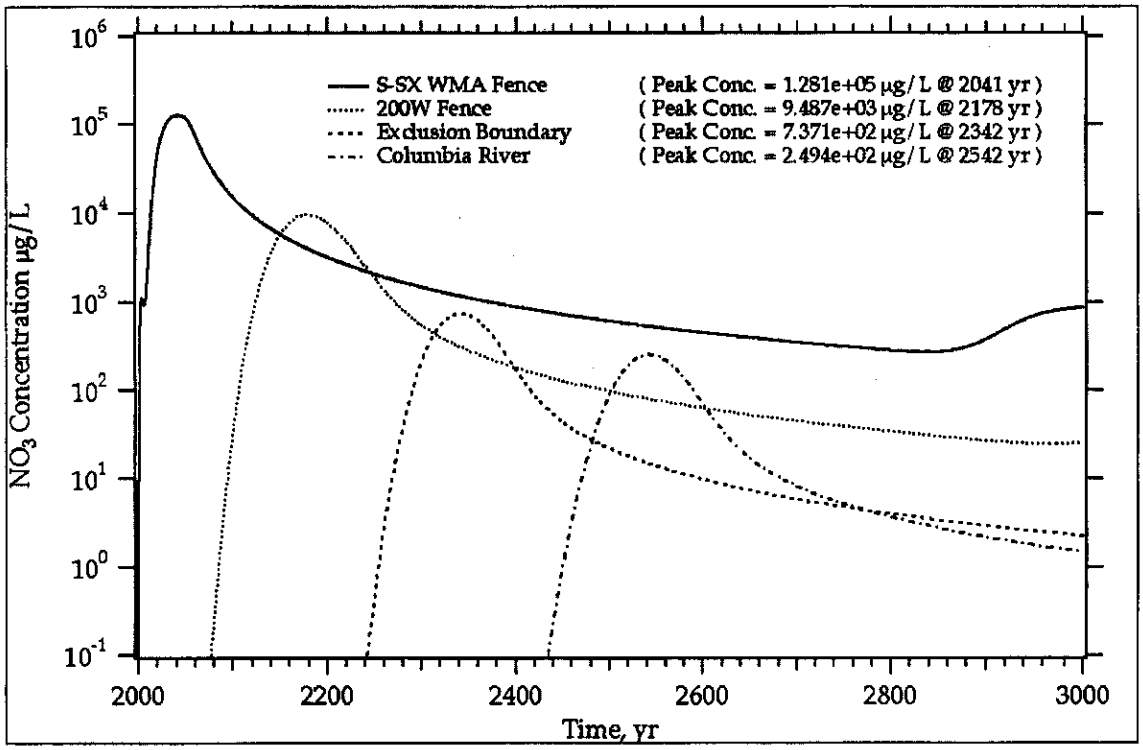


Figure E3.15. Case 1 Area-Weighted Average NO_3 Concentration versus Time at Compliance Points



E3.2.0 CASE 2: BARRIER ALTERNATIVE AND NO WATER-LINE LEAKS

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX–113, -114, and -115; and (c) S-104, -105, and -106 considering placement of an interim barrier by 2010, a closure barrier by 2040 (i.e., the interim barrier replaced by the closure barrier), and no water-line leak.

Figure E3.16. Case 2 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

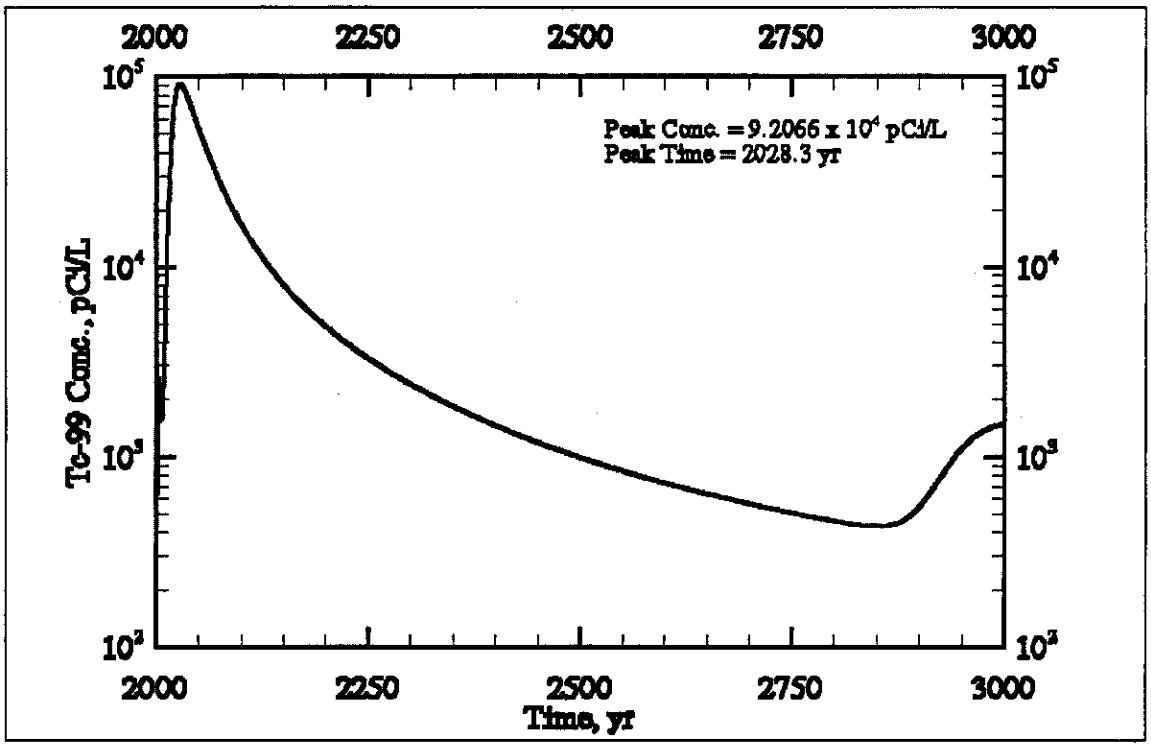


Figure E3.17. Case 2 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

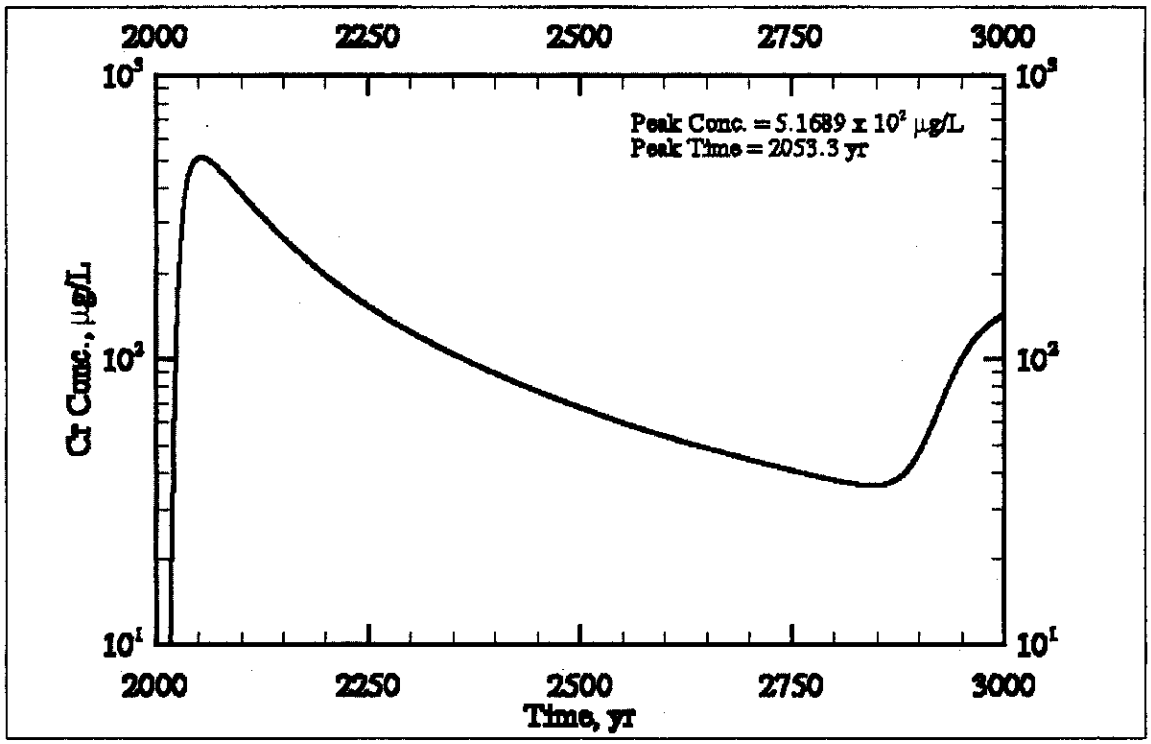


Figure E3.18. Case 2 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

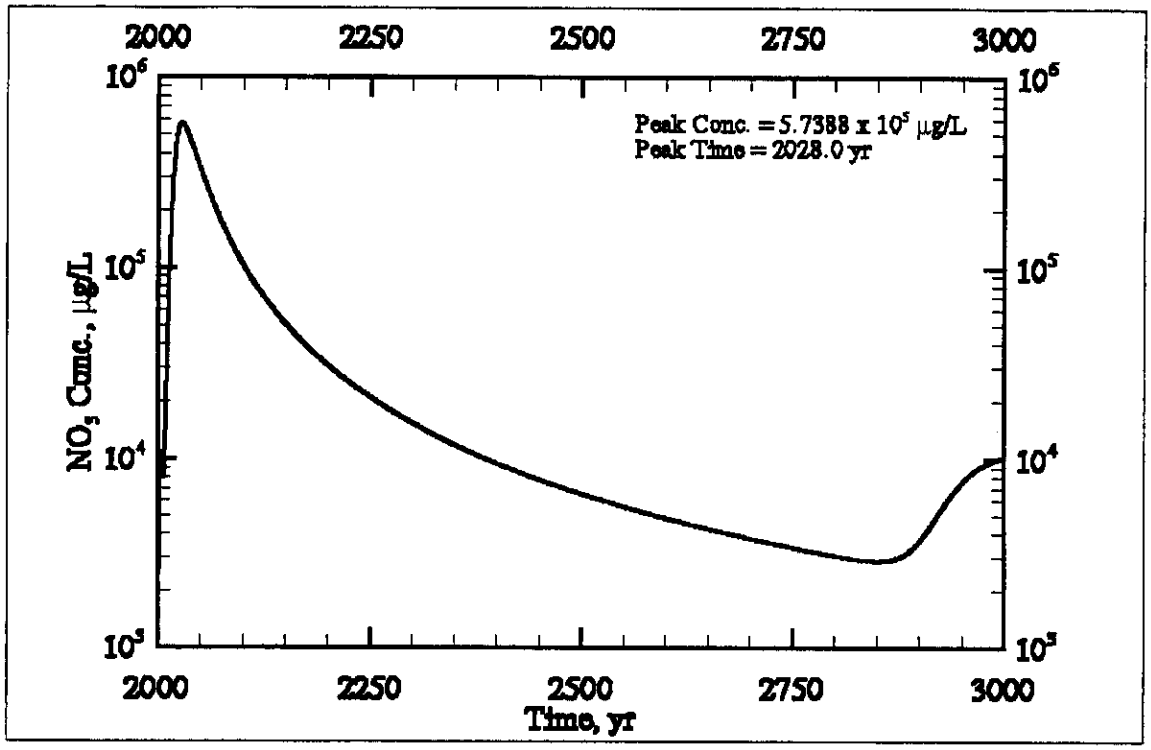


Figure E3.19. Case 2 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

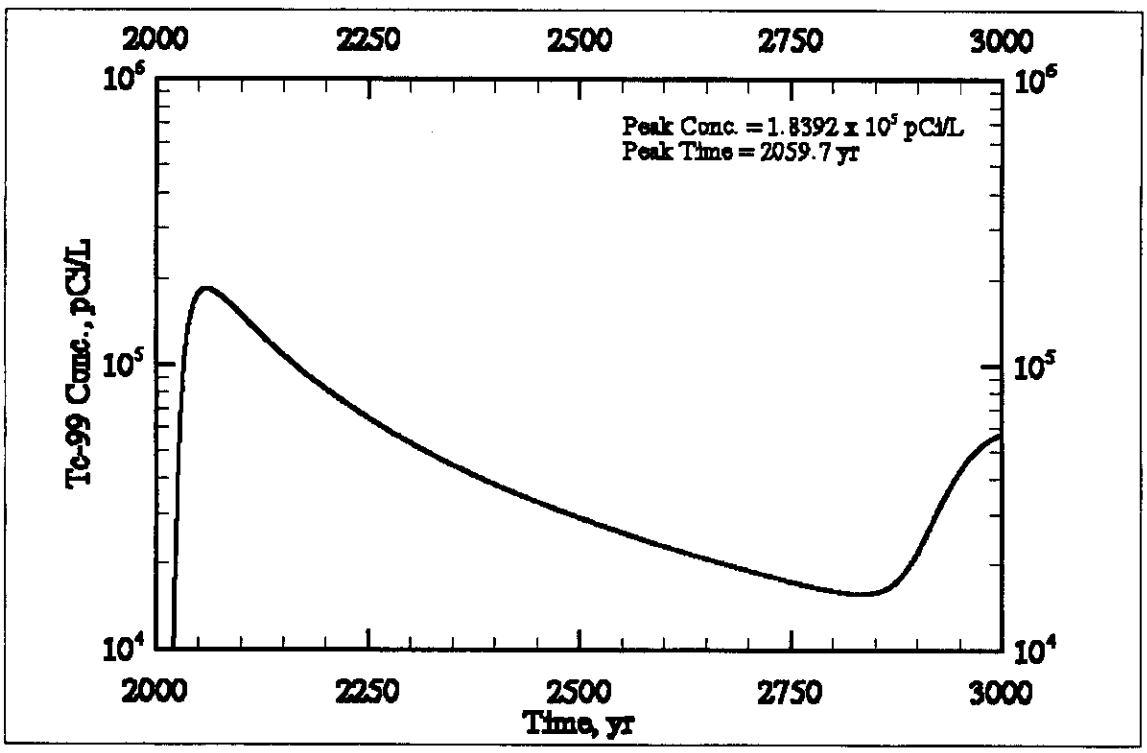


Figure E3.20. Case 2 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

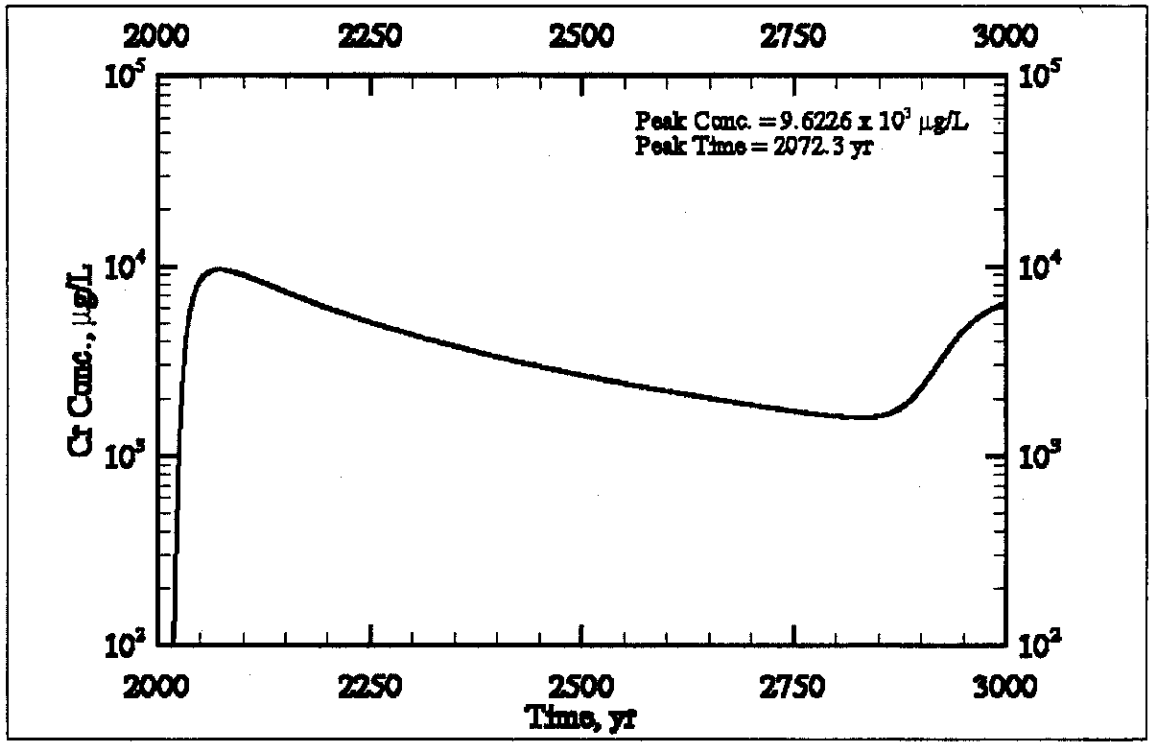


Figure E3.21. Case 2 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

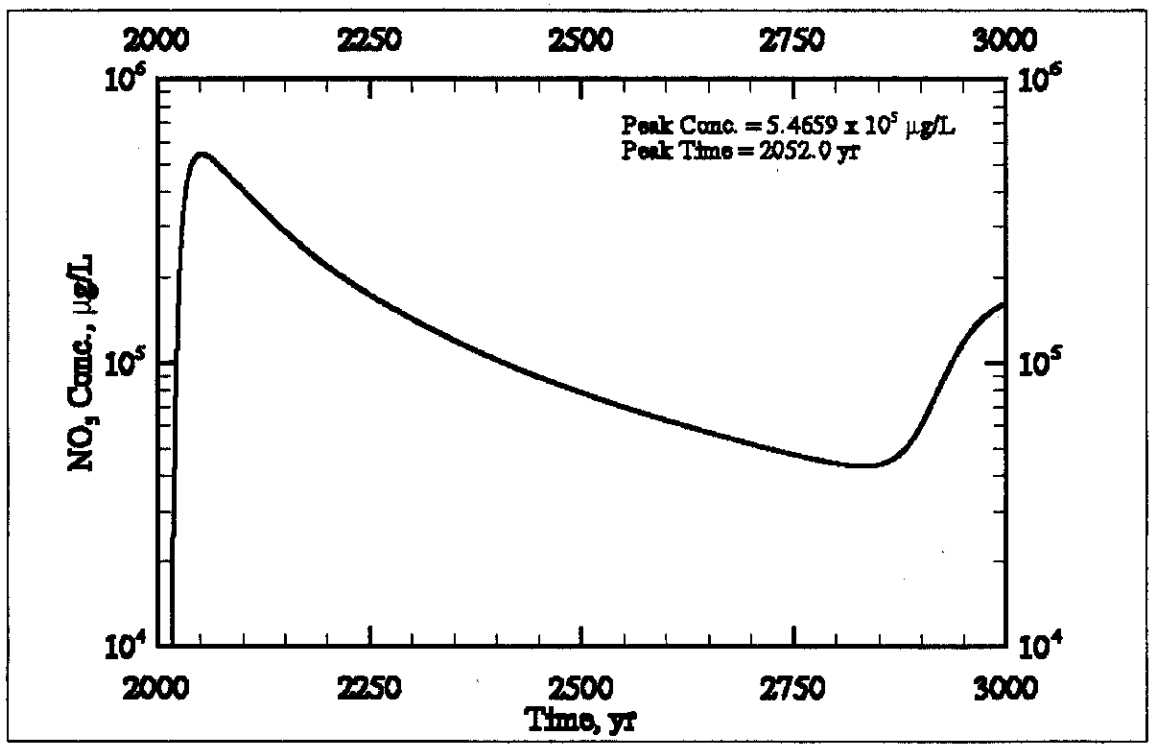


Figure E3.22. Case 2 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

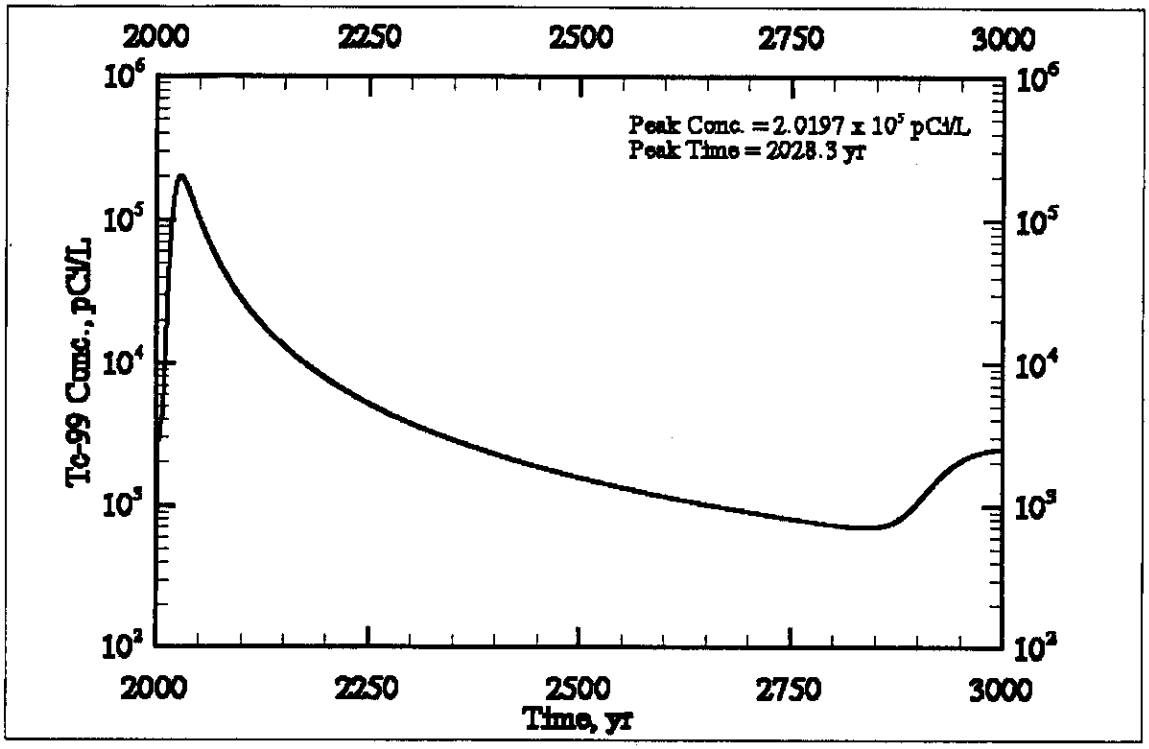


Figure E3.23. Case 2 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

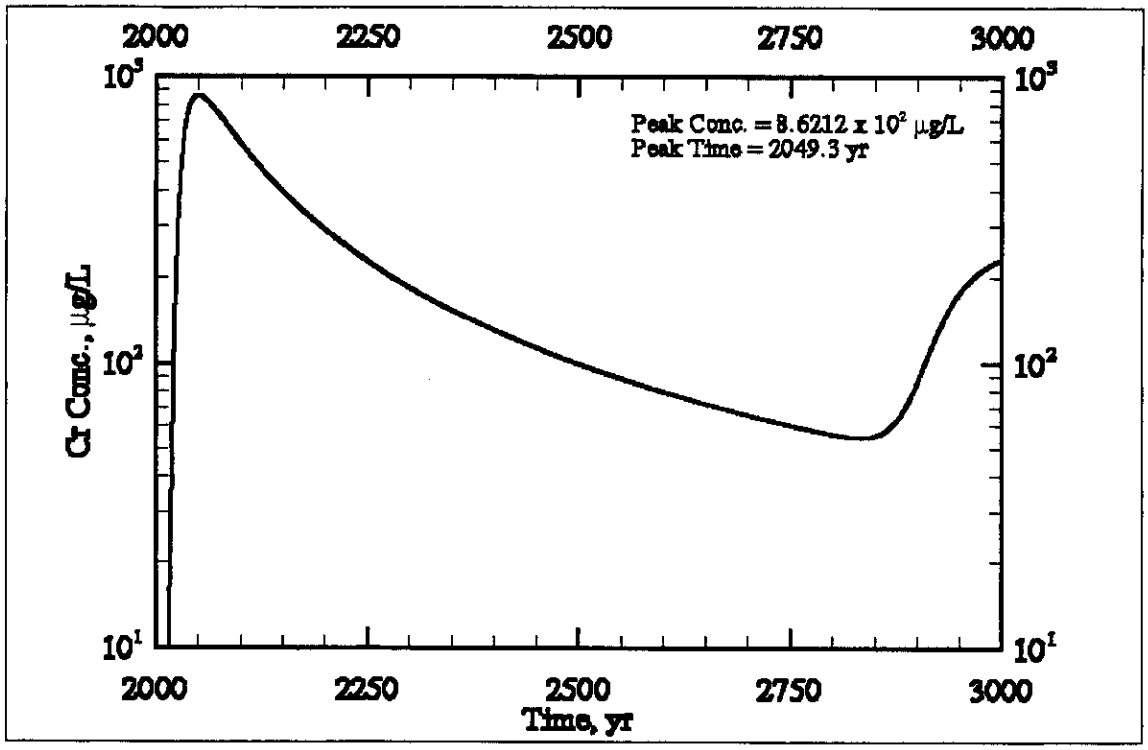


Figure E3.24. Case 2 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

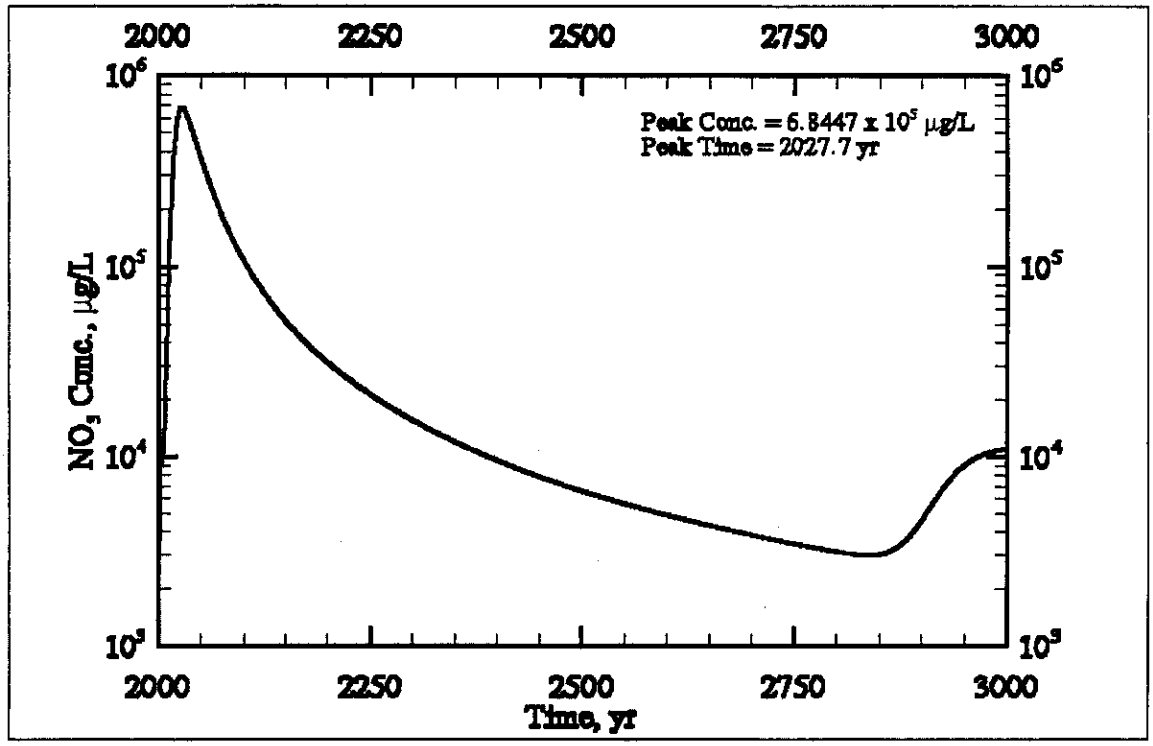


Figure E3.25. Case 2 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

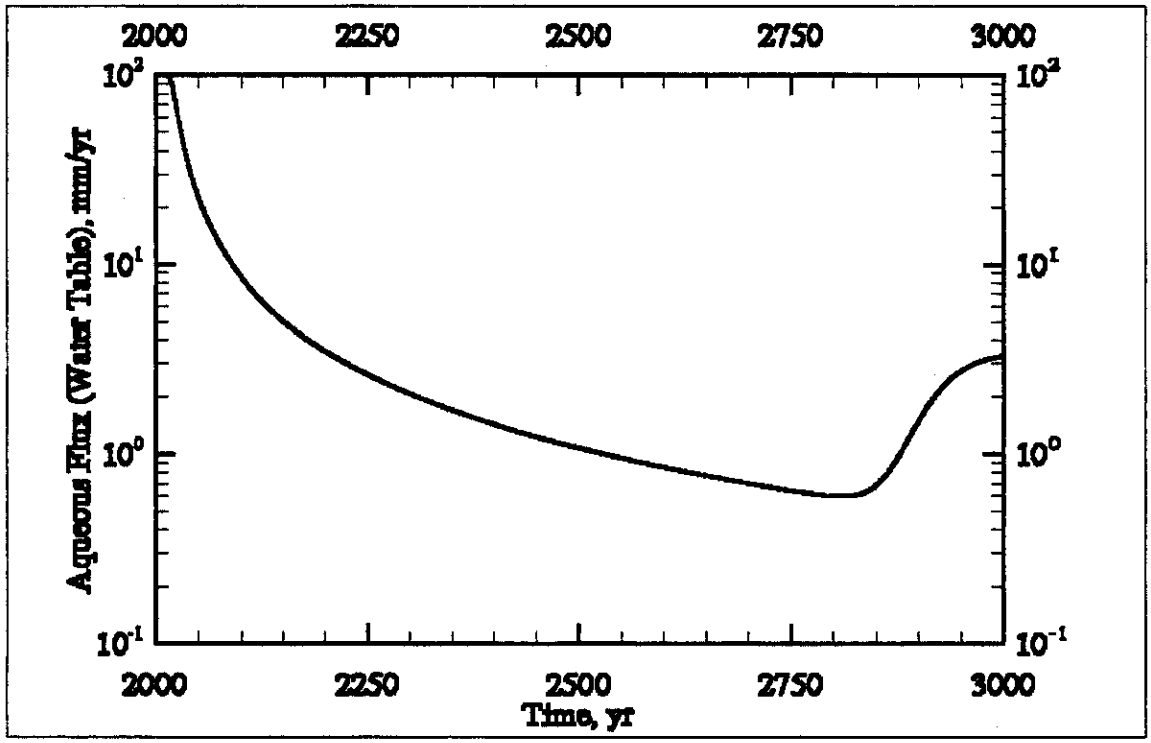


Figure E3.26. Case 2 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (S-107, -108, -109)

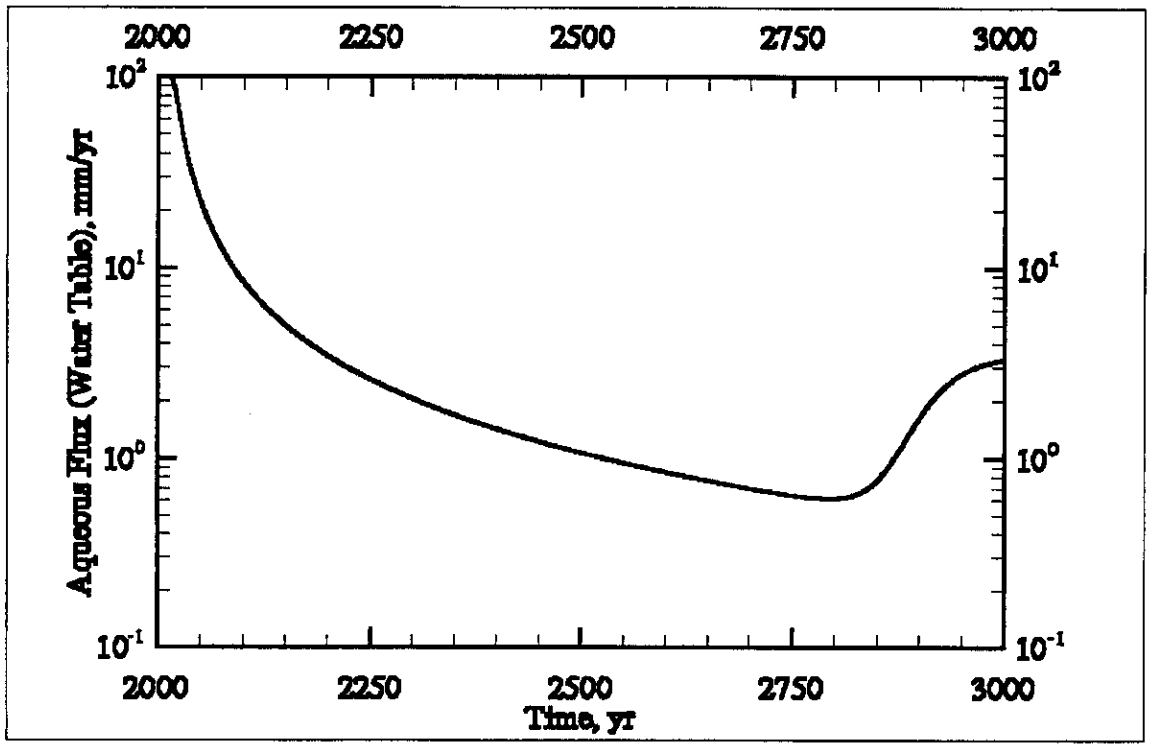


Figure E3.27. Case 2 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

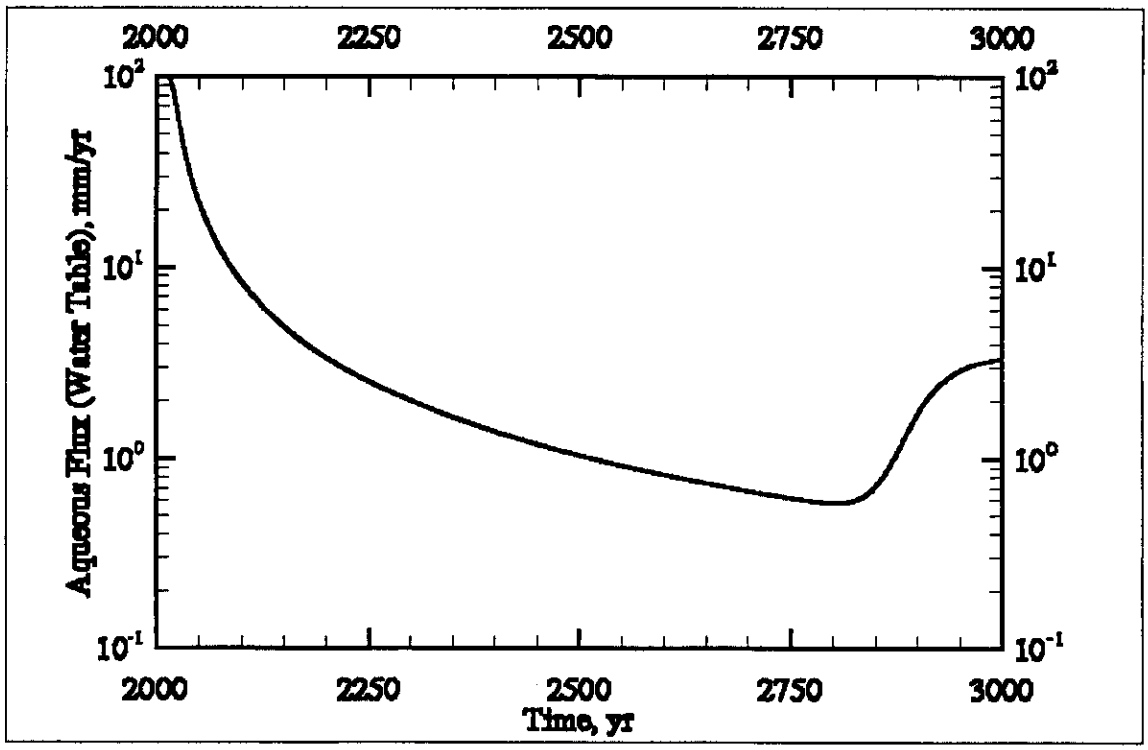


Figure E3.28. Case 2 Area-Weighted Average Tc-99 Concentration and Dose versus Time at Compliance Points

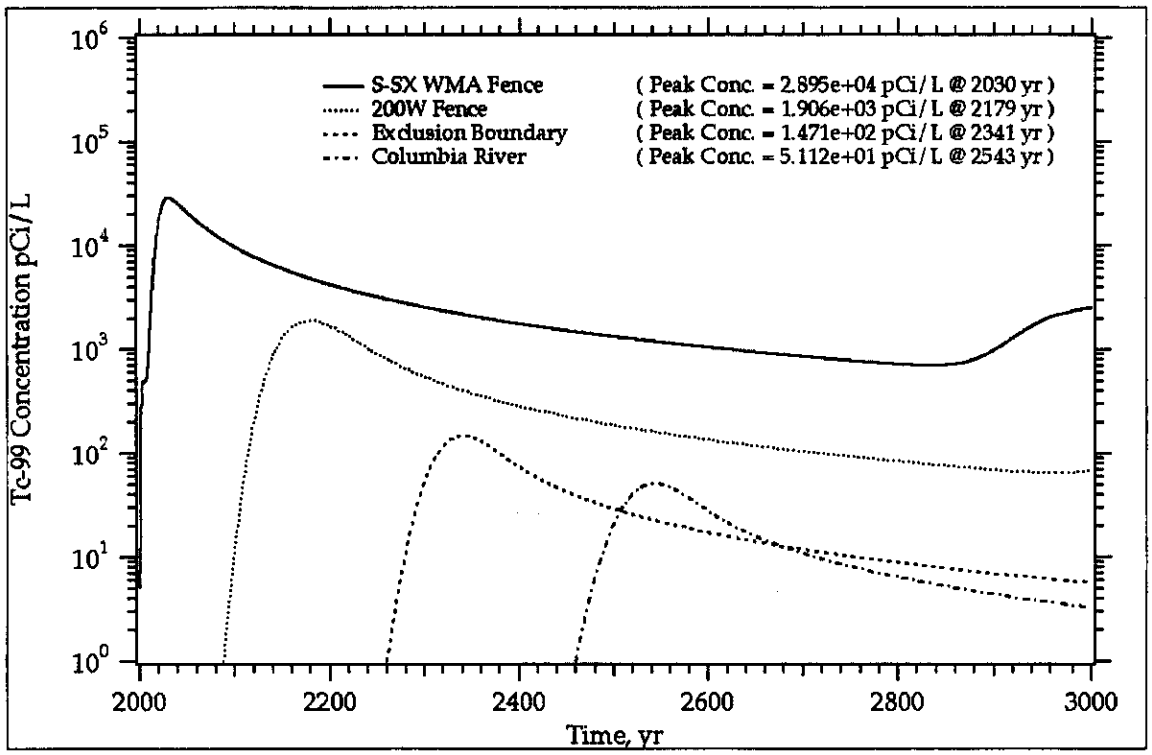


Figure E3.29. Case 2 Area-Weighted Average Cr Concentration versus Time at Compliance Points

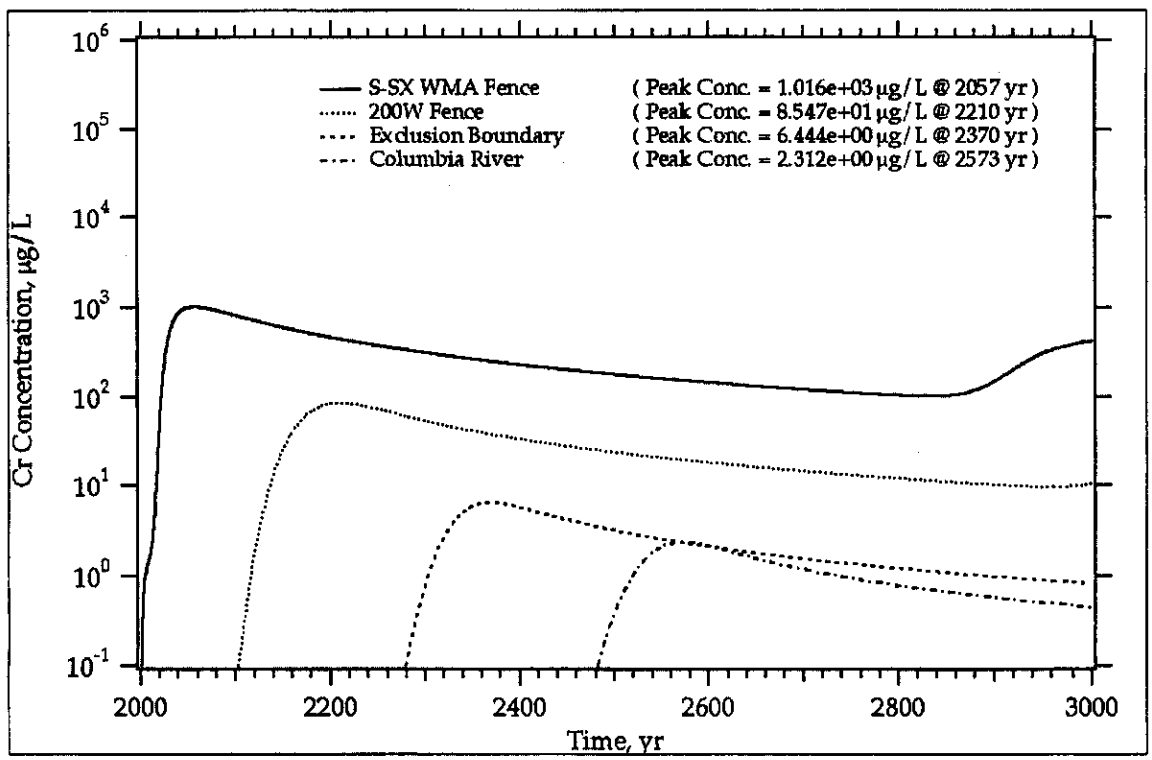
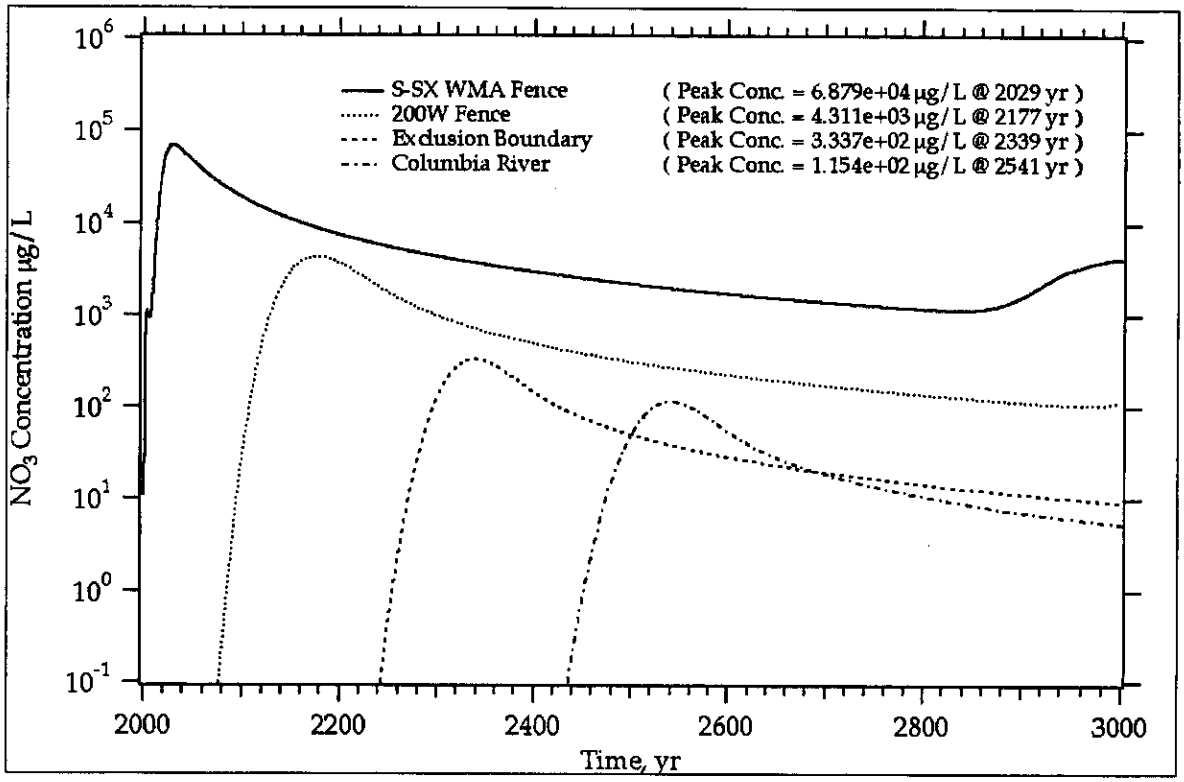


Figure E3.30. Case 2 Area-Weighted Average NO_3 Concentration versus Time at Compliance Points



E3.3.0 CASE 3: NO BARRIER AND WATER-LINE LEAK (25,000 IN 5 DAYS)

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration, water-line leak (25,000 gal in 5 days) for tank SX-115 only, and no barrier until closure in 2040.

Figure E3.31. Case 3 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

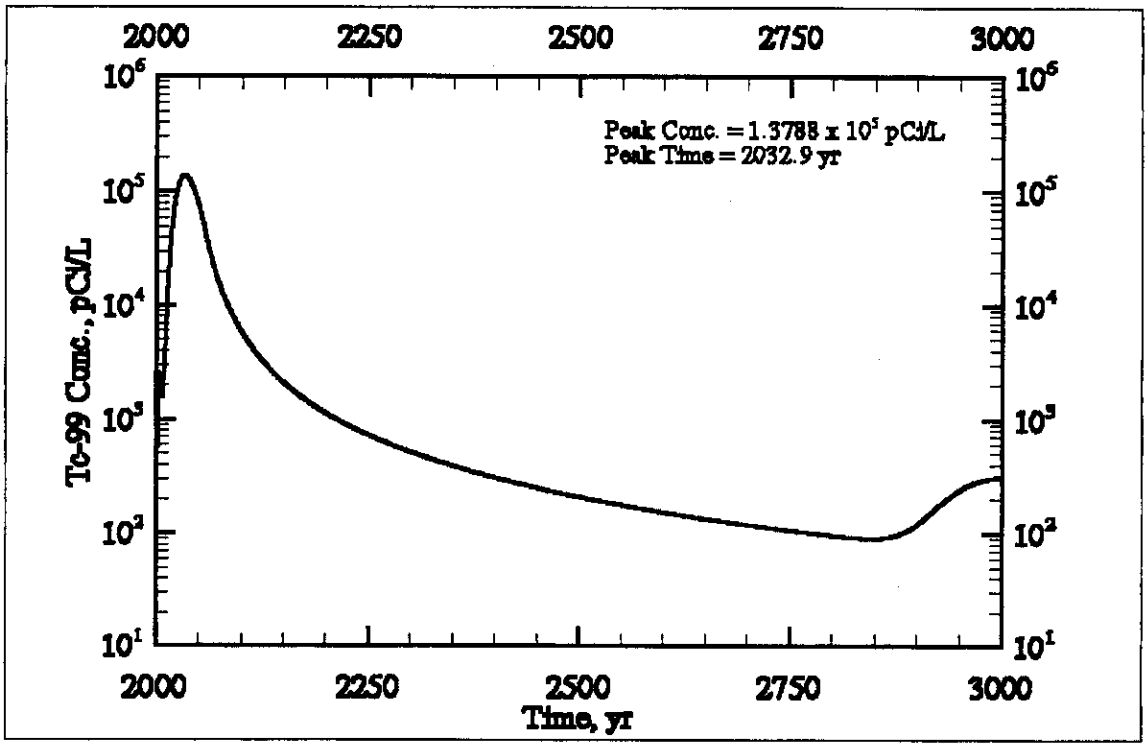


Figure E3.32. Case 3 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

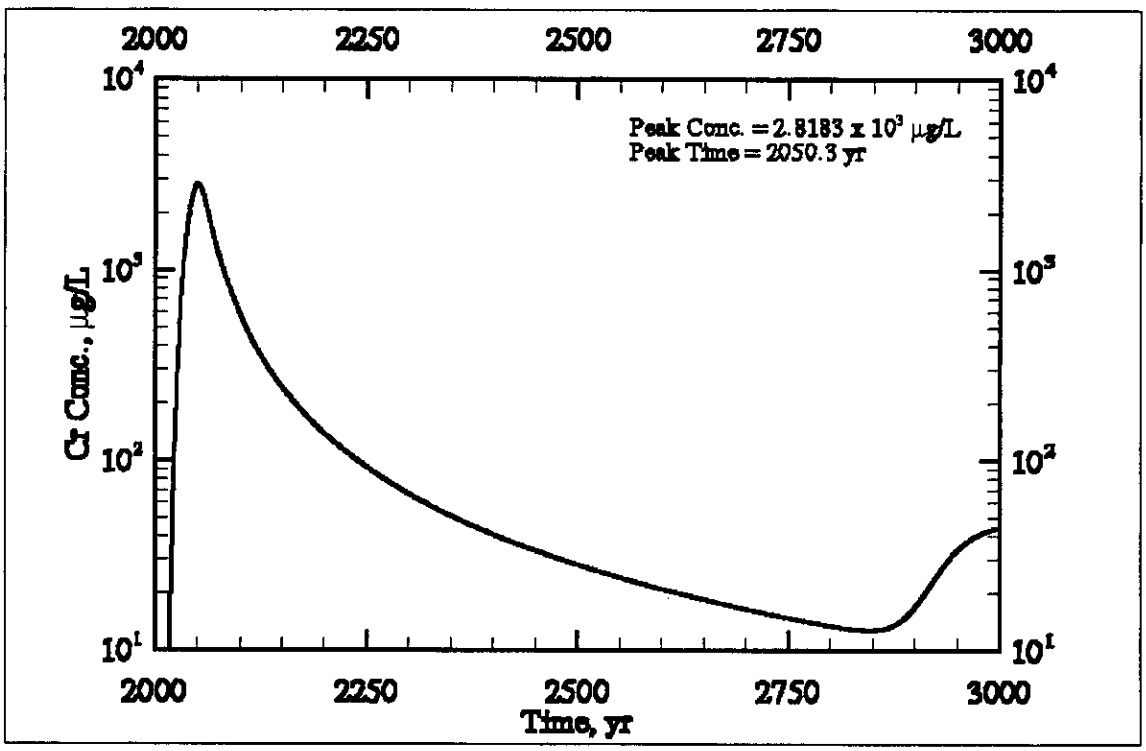


Figure E3.33. Case 3 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

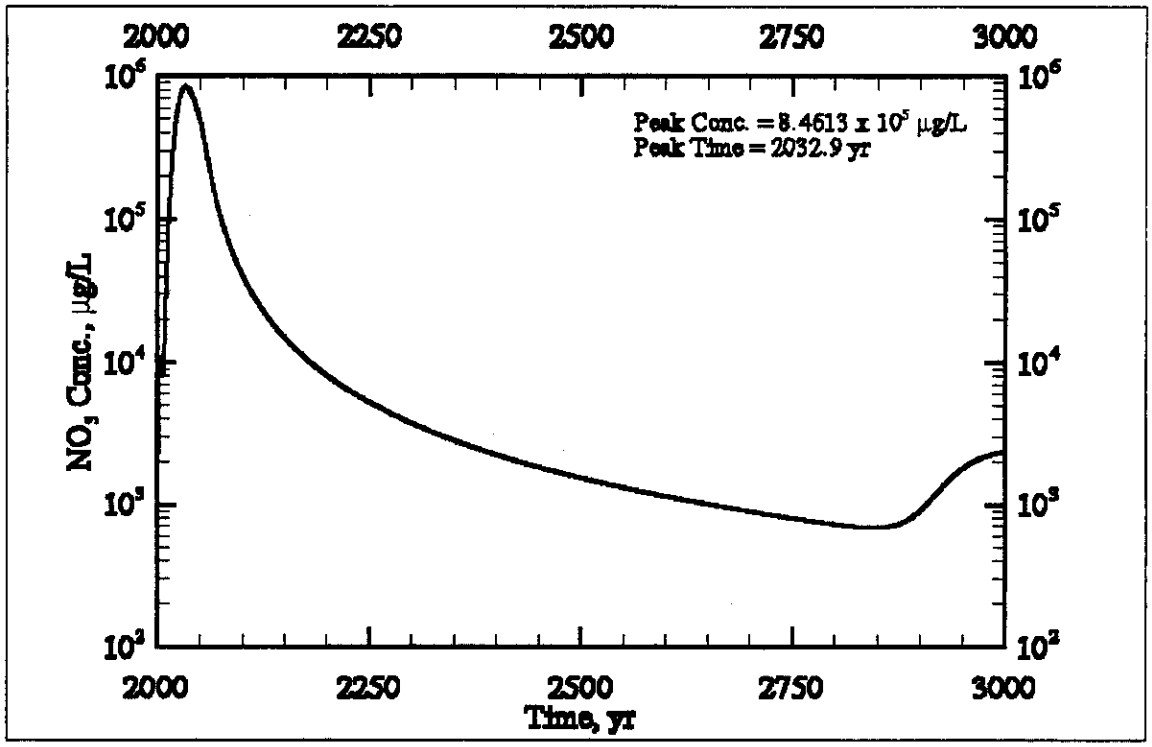


Figure E3.34. Case 3 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

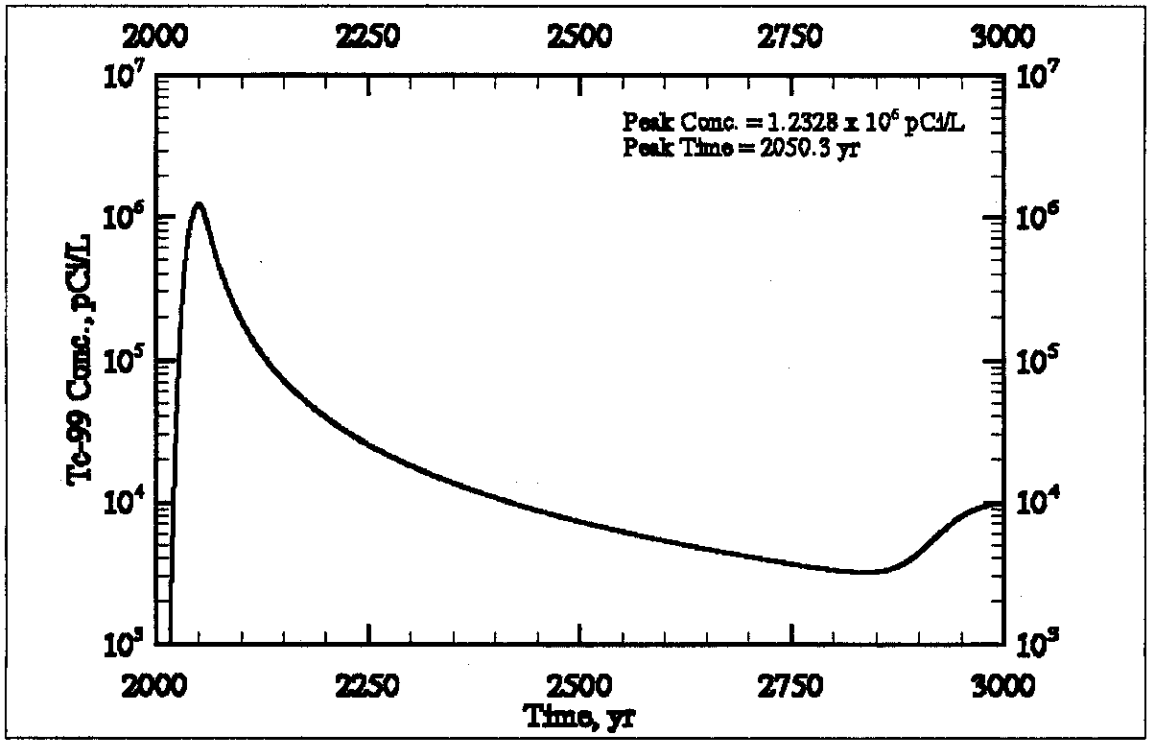


Figure E3.35. Case 3 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

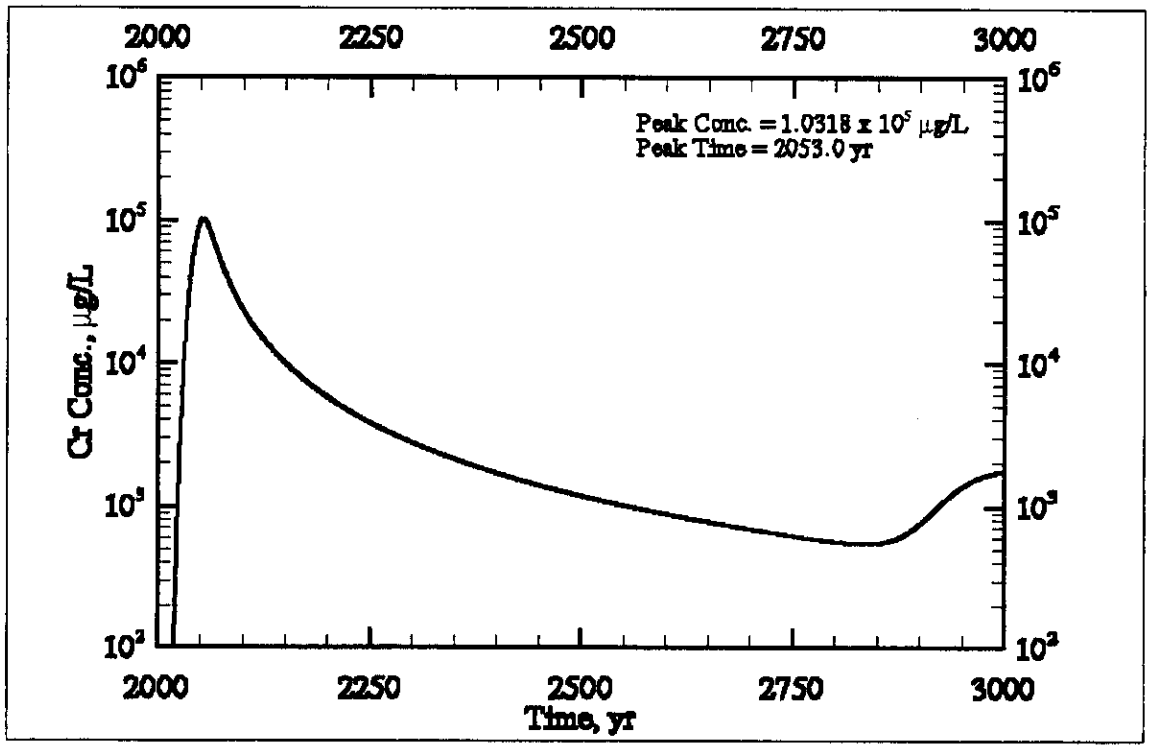


Figure E3.36. Case 3 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

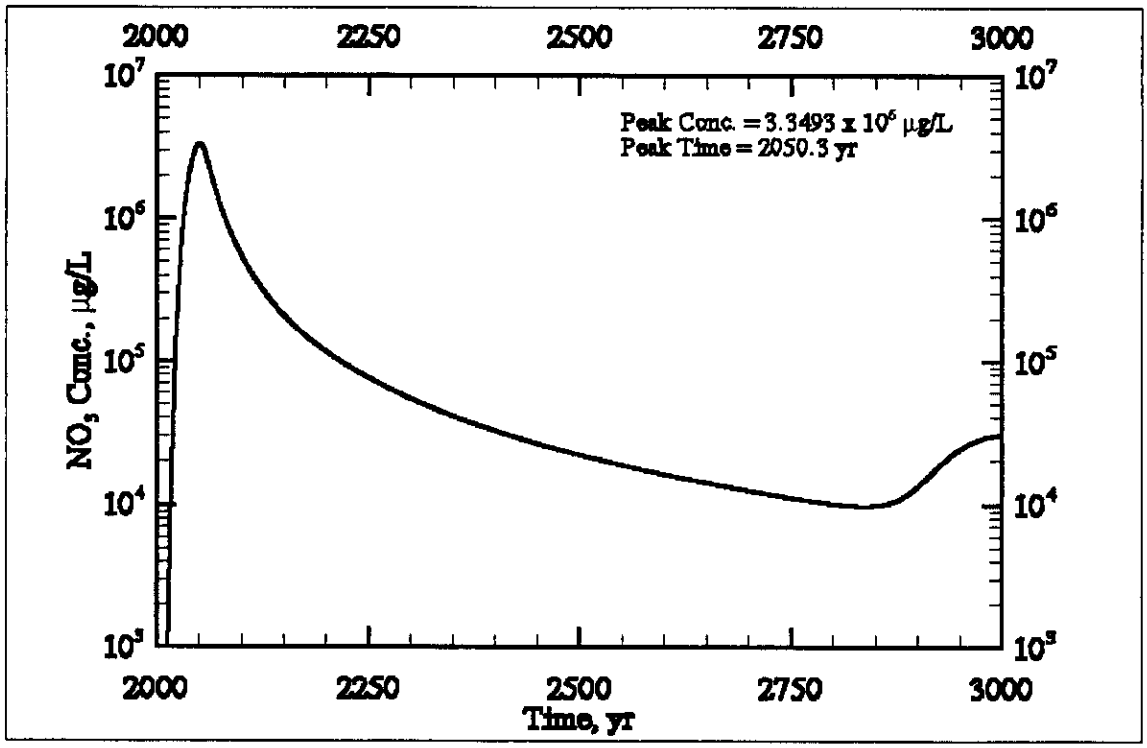


Figure E3.37. Case 3 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

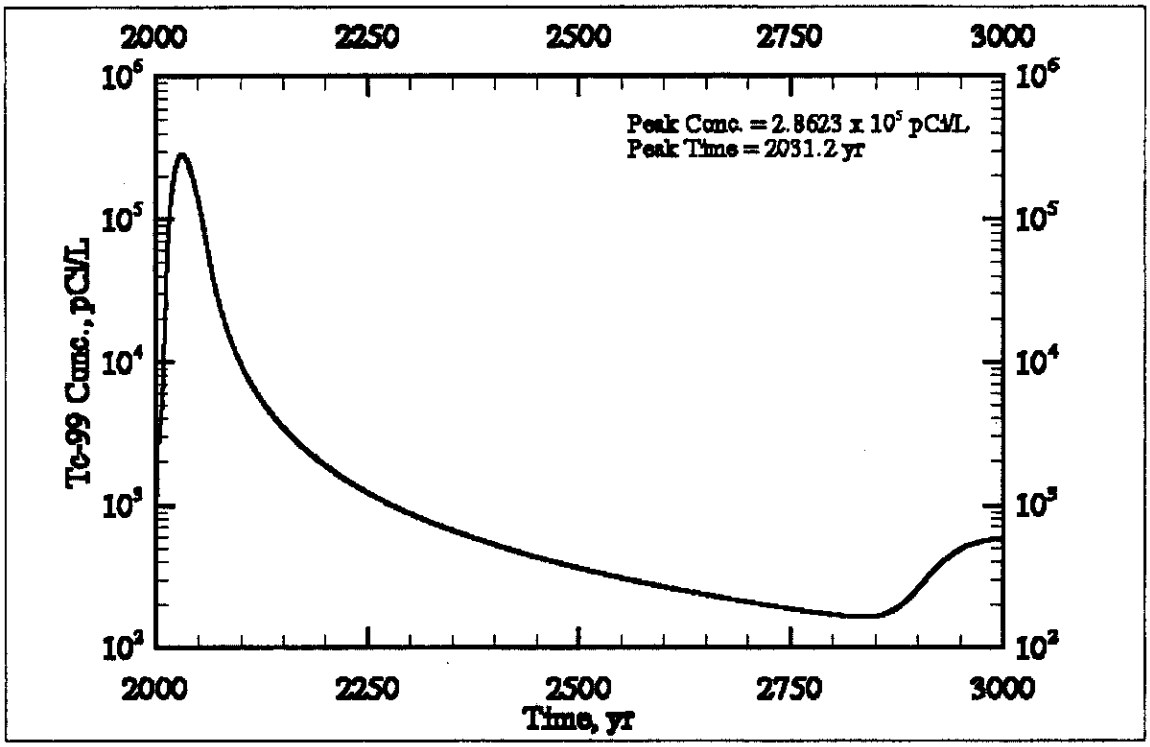


Figure E3.38. Case 3 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

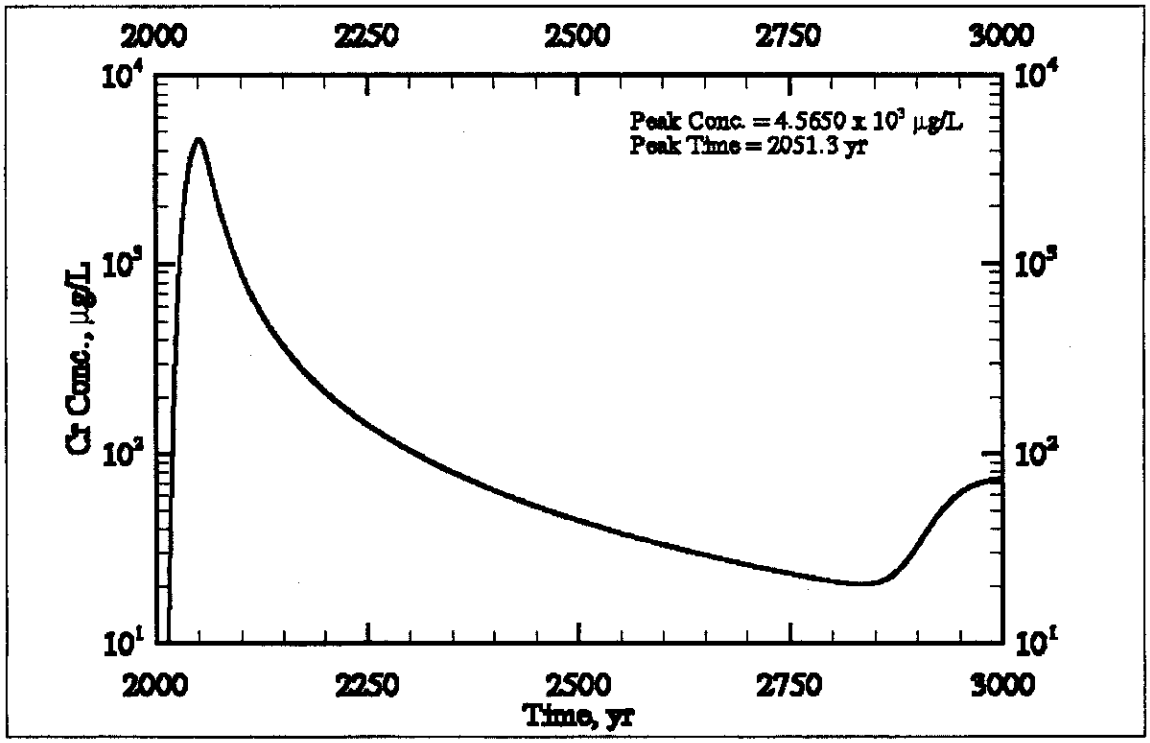


Figure E3.39. Case 3 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

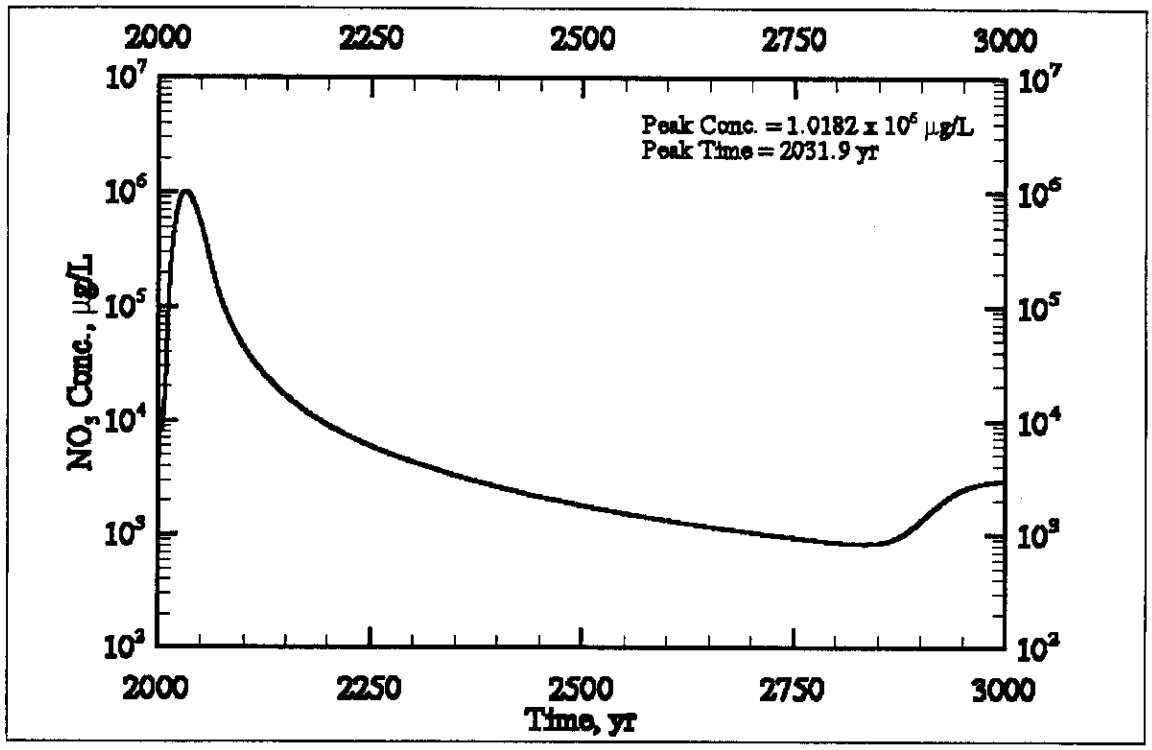


Figure E3.40. Case 3 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

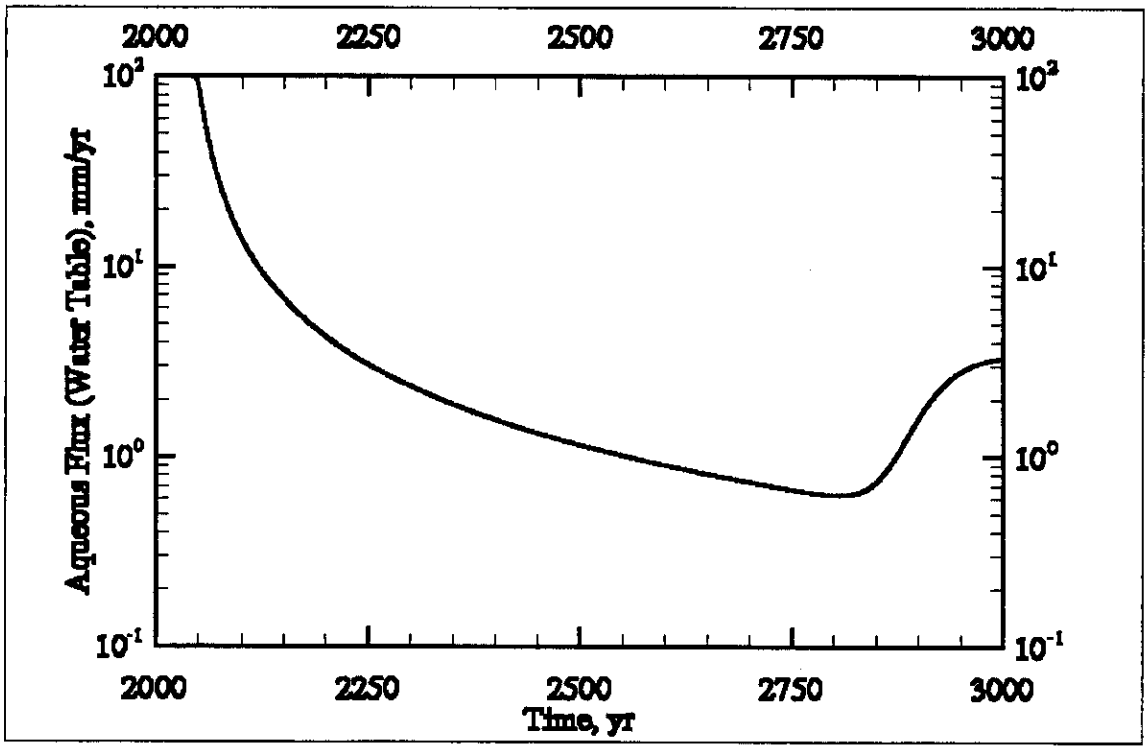


Figure E3.41. Case 3 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

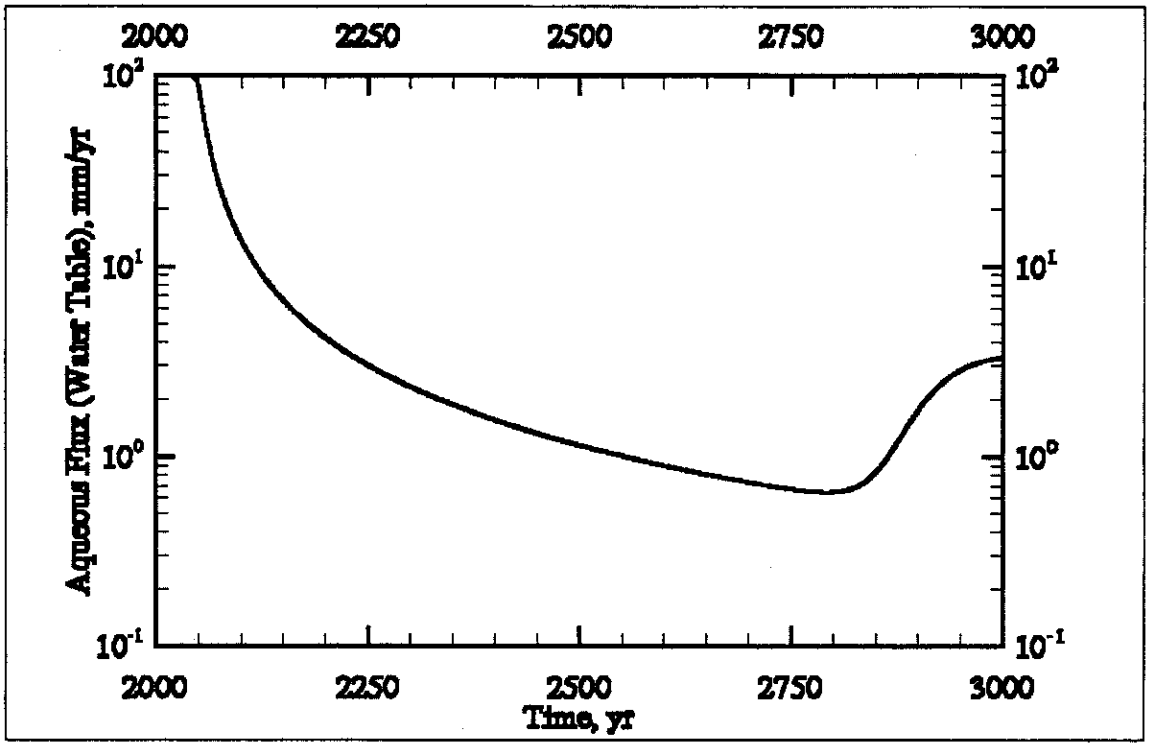


Figure E3.42. Case 3 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

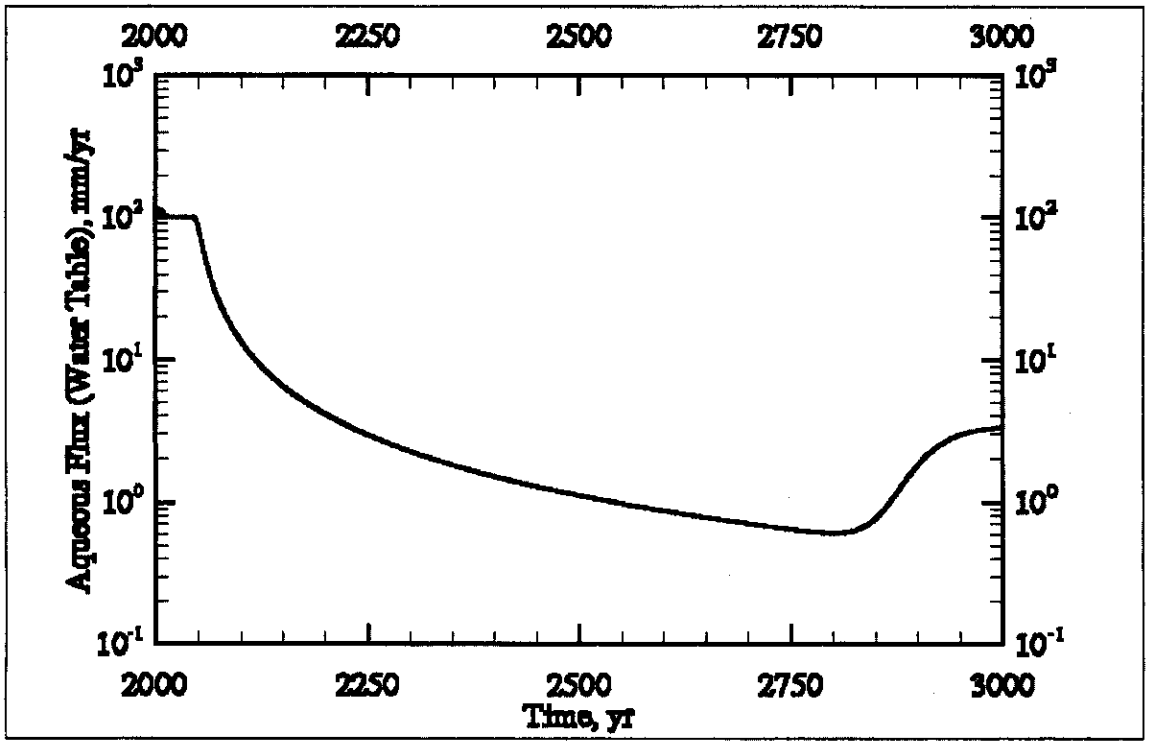


Figure E3.43. Case 3 Area-Weighted Average Tc-99 Concentration and Dose versus Time at Compliance Points

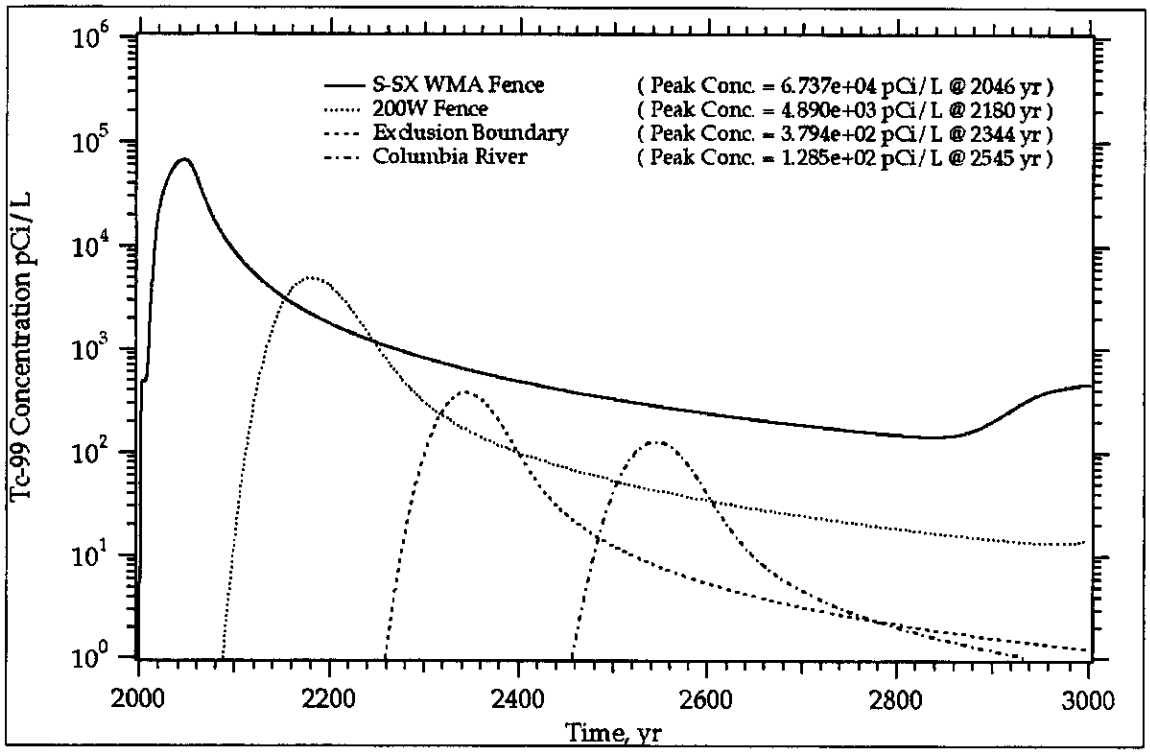


Figure E3.44. Case 3 Area-Weighted Average Cr Concentration versus Time at Compliance Points

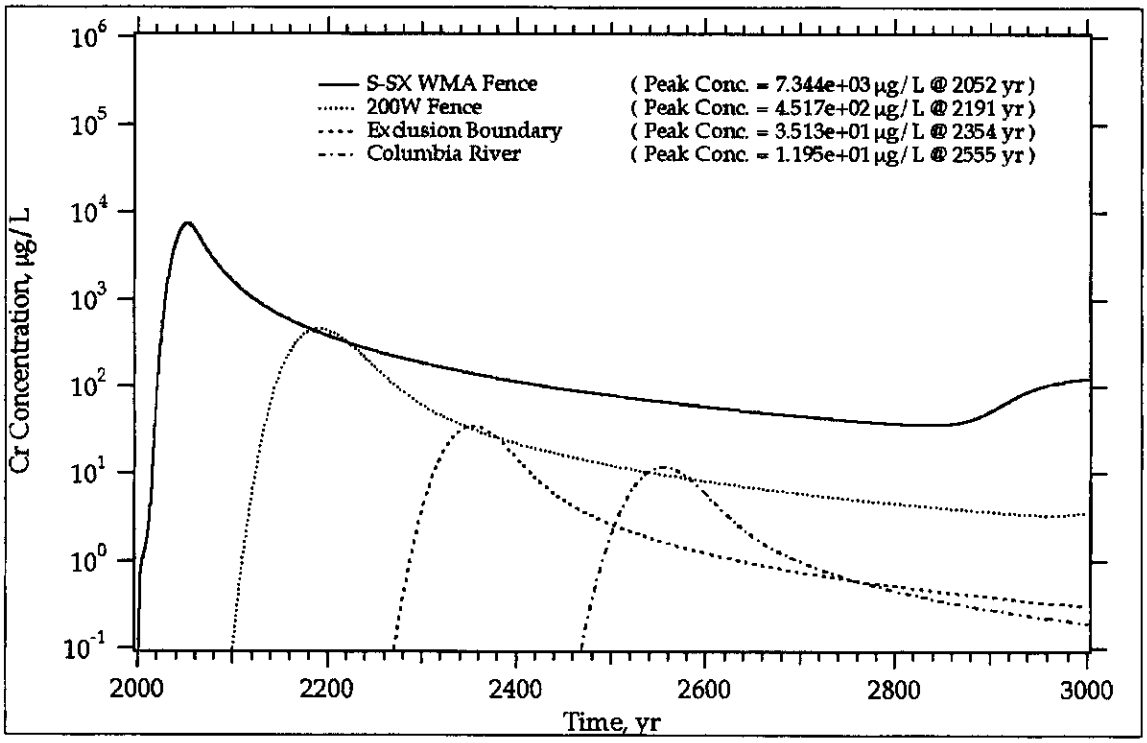
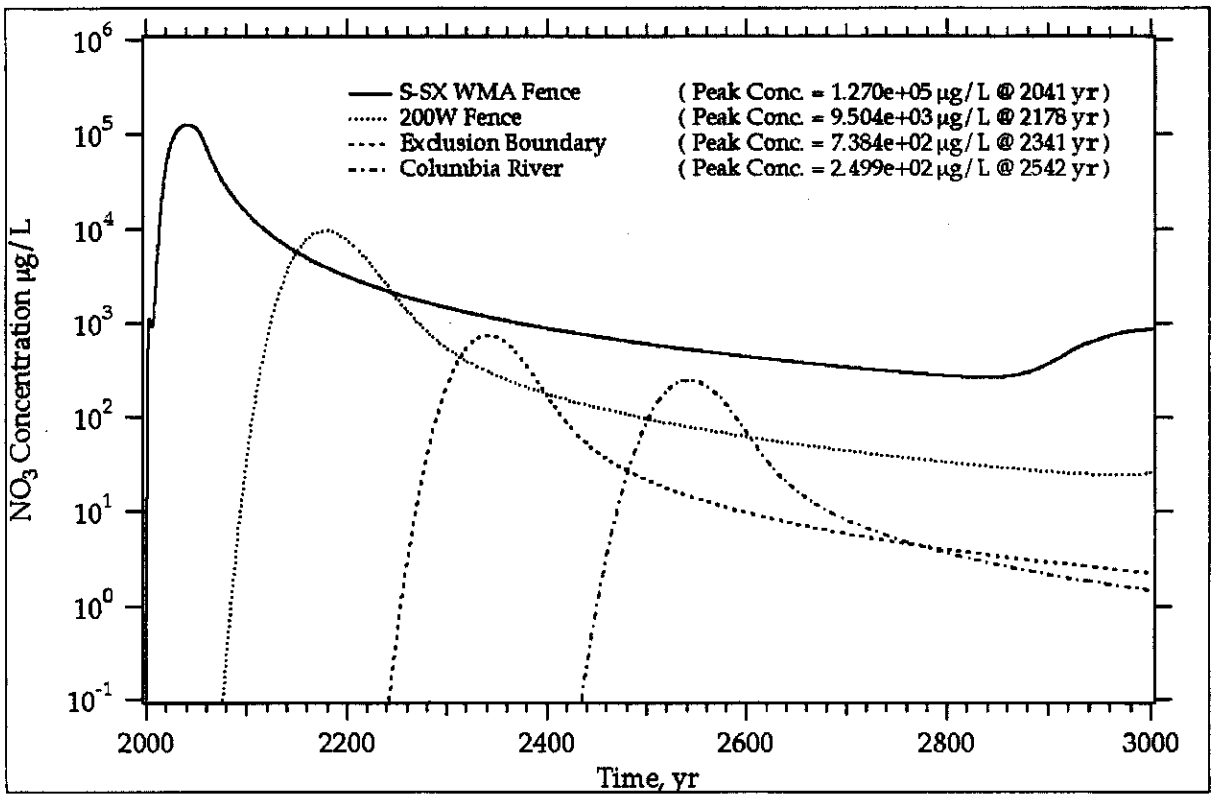


Figure E3.45. Case 3 Area-Weighted Average NO_3 Concentration versus Time at Compliance Points



E3.4.0 CASE 4: NO BARRIER AND CLASTIC DIKES

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration, clastic dikes between tanks SX-107, -108, and -109, and no barrier until closure in 2040.

Figure E3.46. Case 4 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

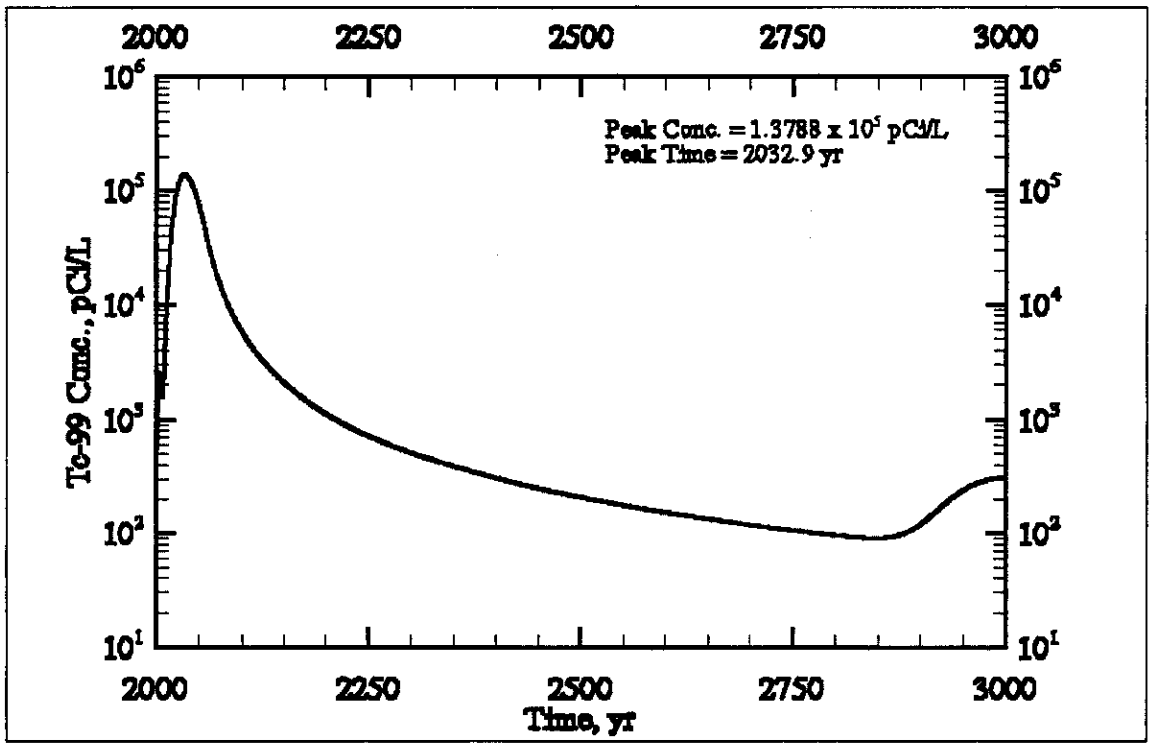


Figure E3.47. Case 4 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

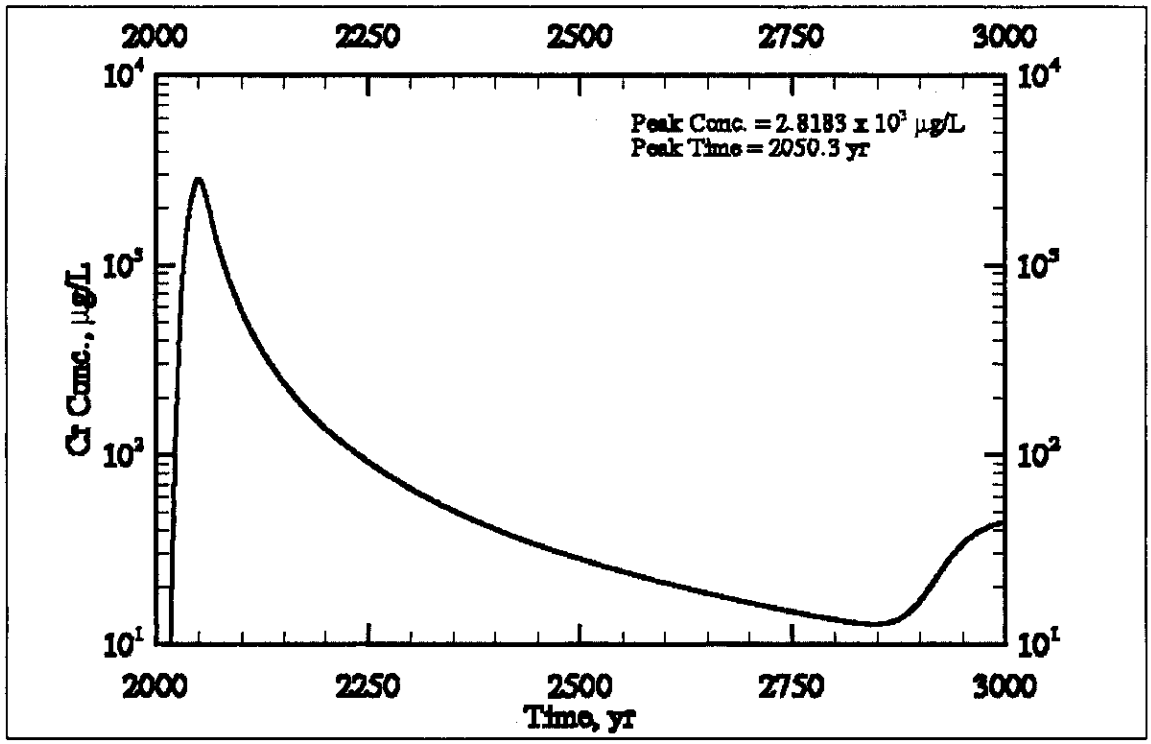


Figure E3.48. Case 4 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

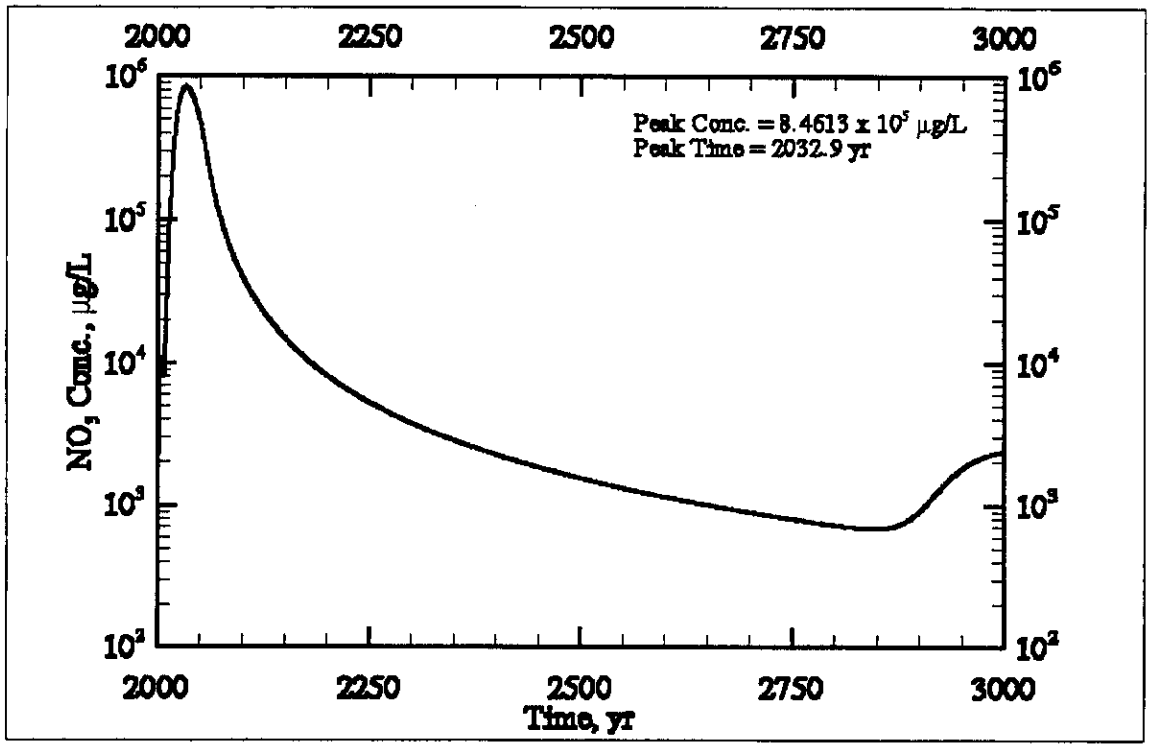


Figure E3.49. Case 4 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

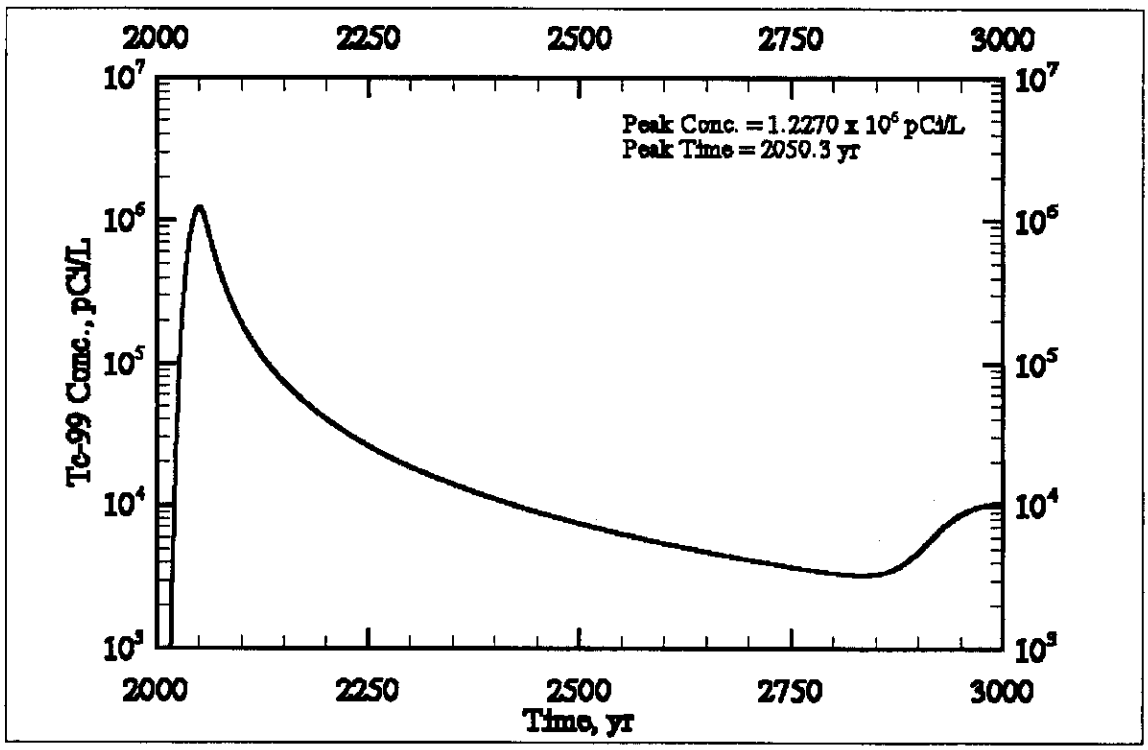


Figure E3.50. Case 4 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

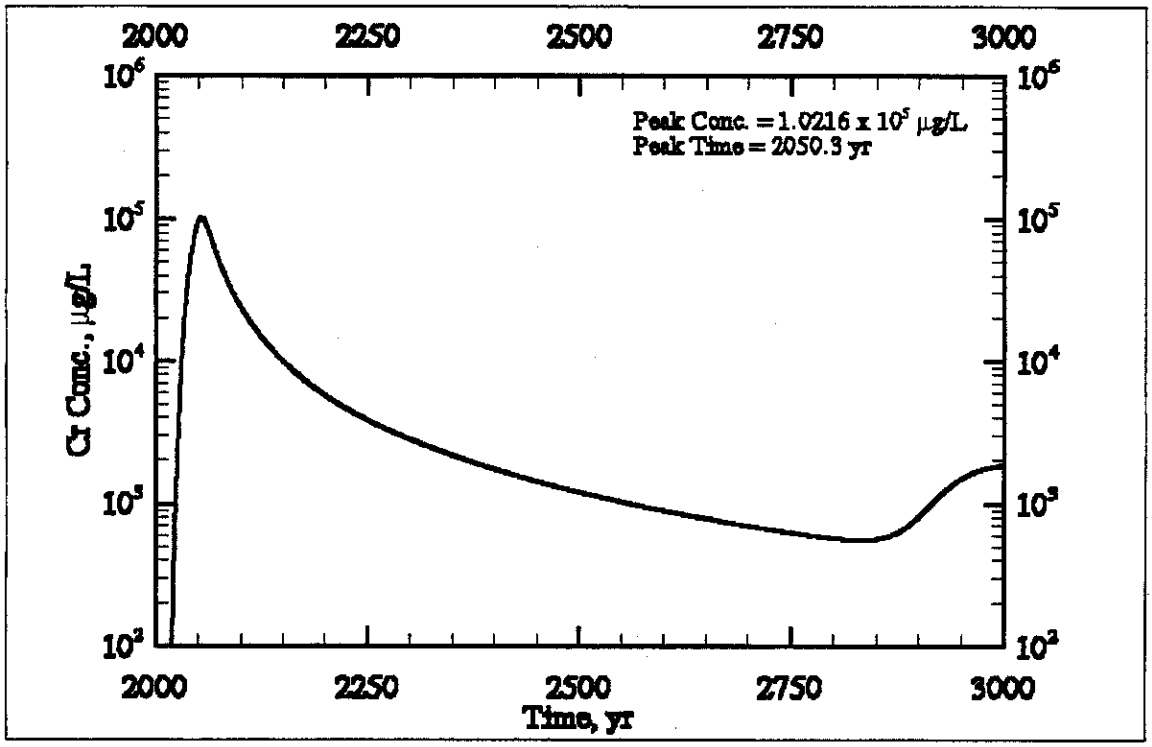


Figure E3.51. Case 4 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

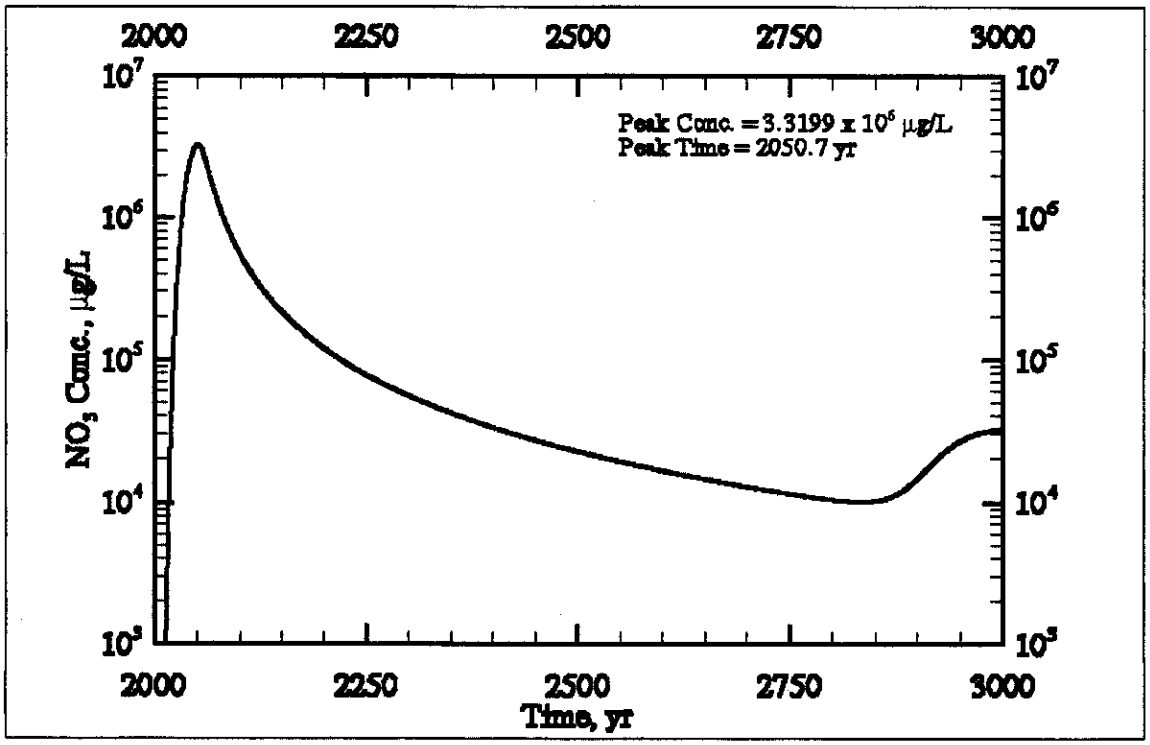


Figure E3.52. Case 4 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

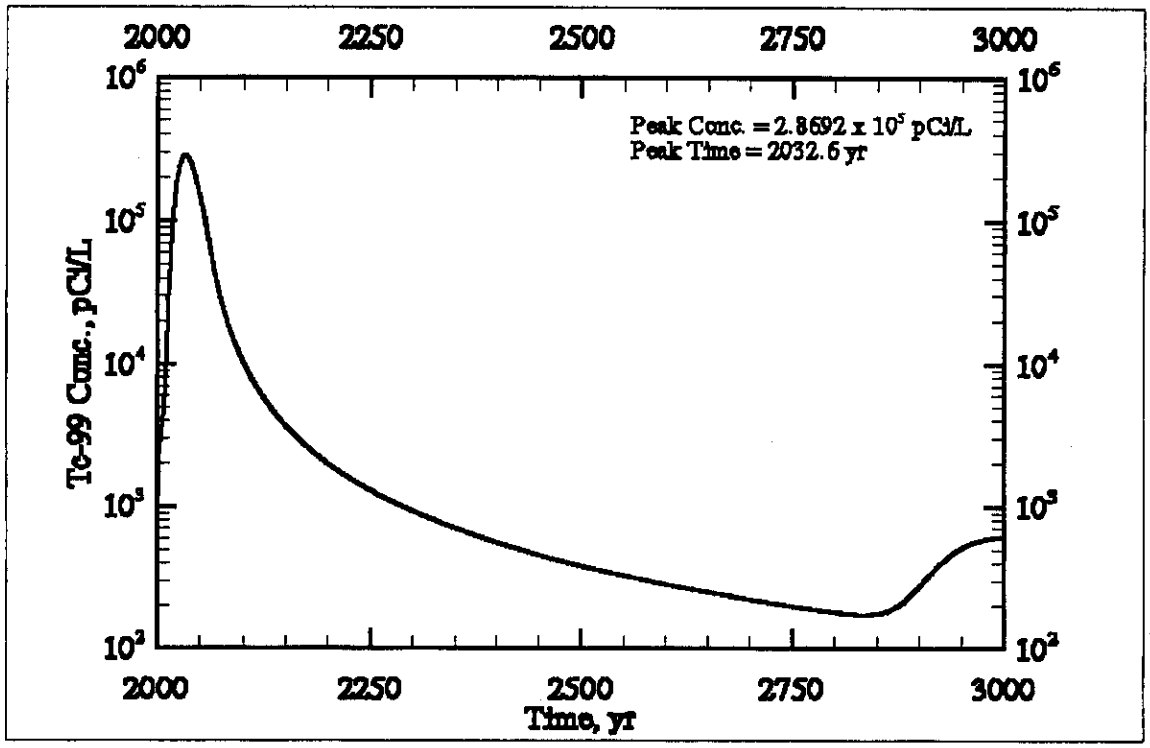


Figure E3.53. Case 4 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

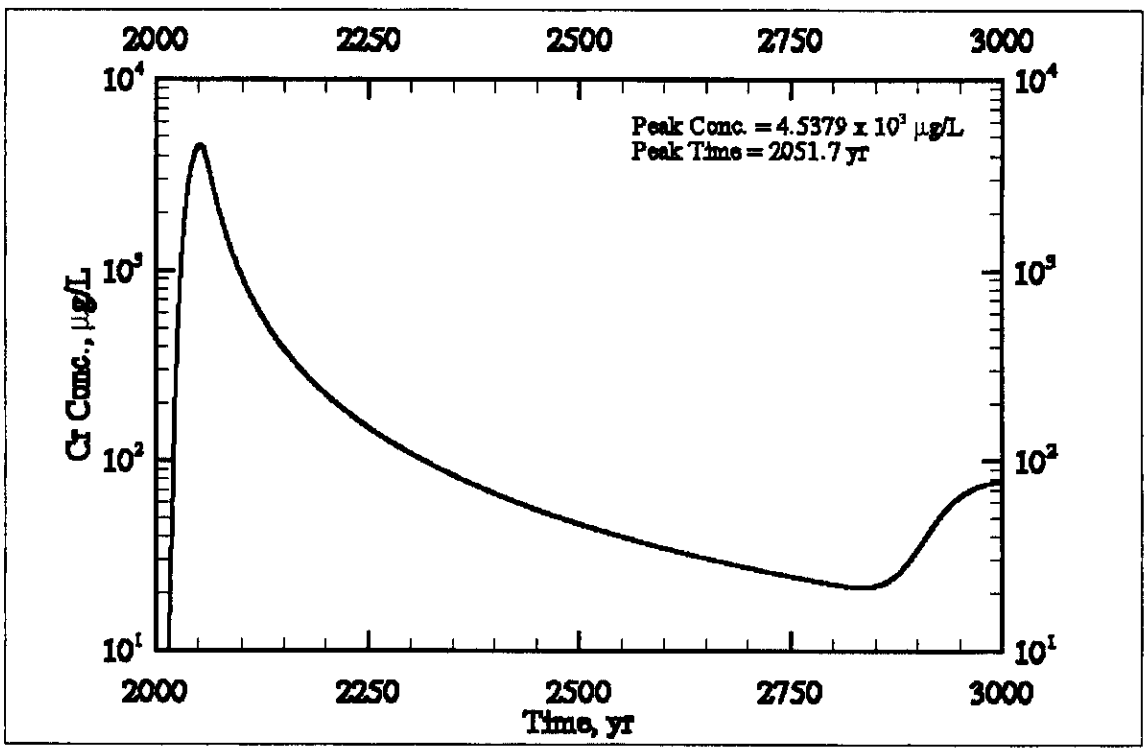


Figure E3.54. Case 4 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

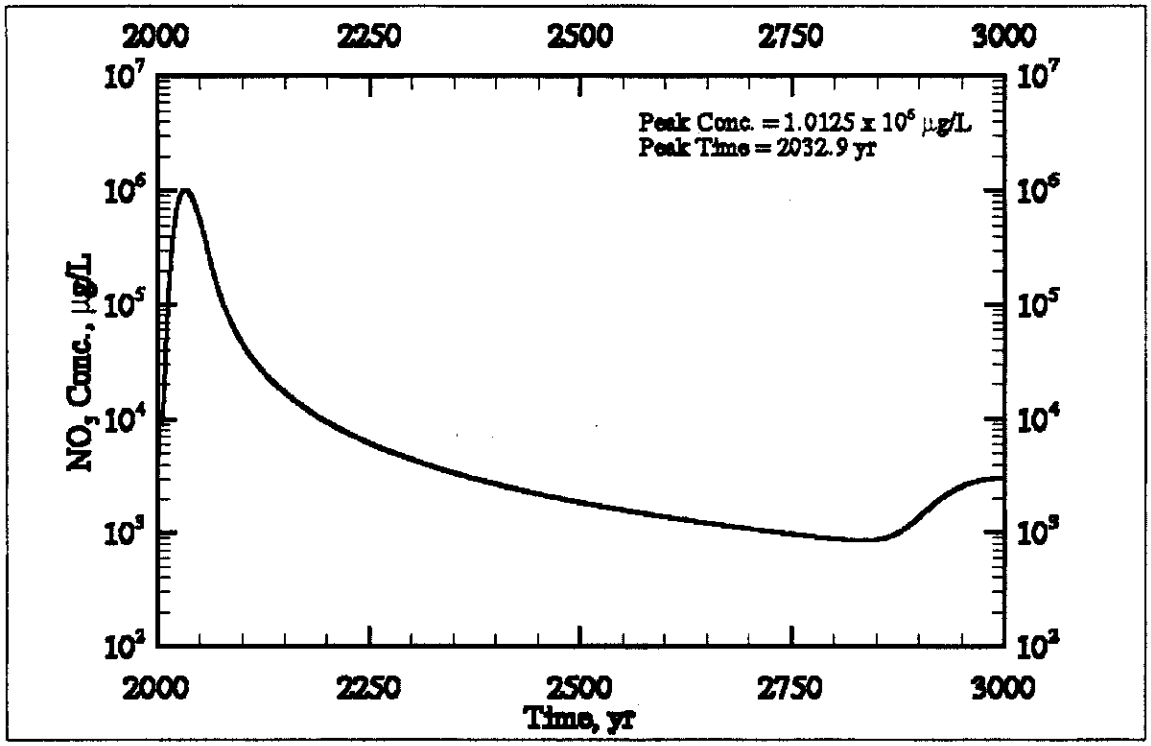


Figure E3.55. Case 4 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

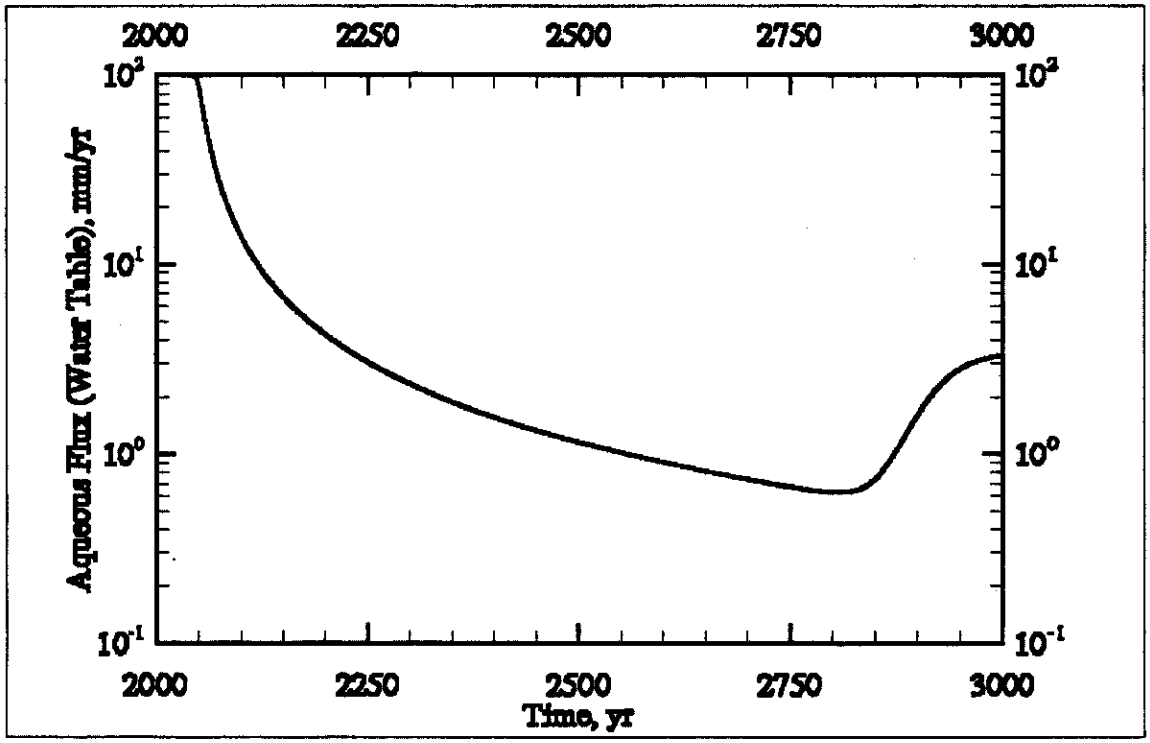


Figure E3.56. Case 4 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

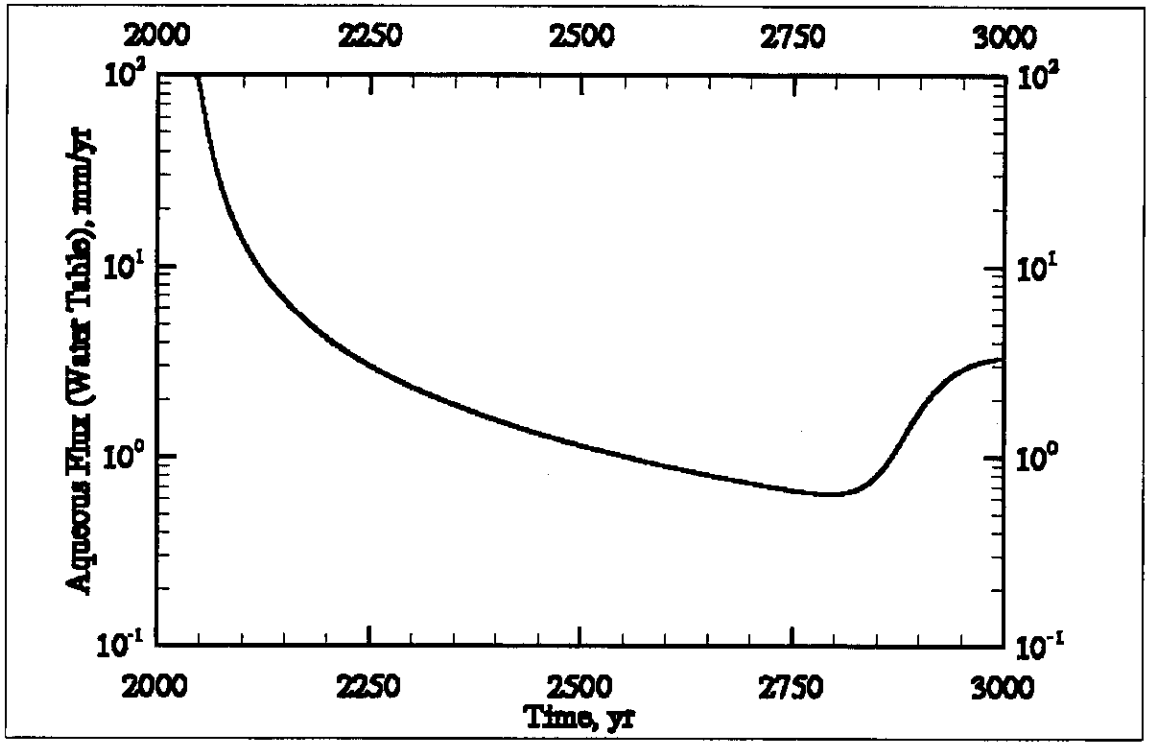


Figure E3.57. Case 4 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

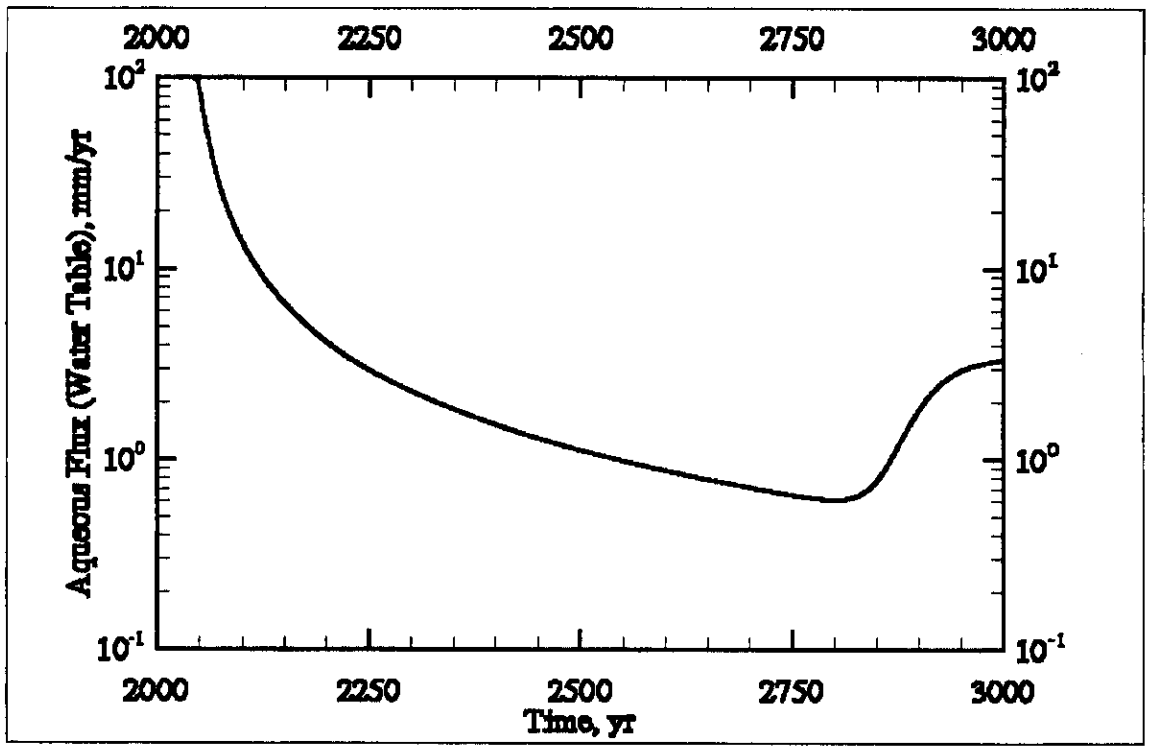


Figure E3.58. Case 4 Area-Weighted Average Tc-99 Concentration and Dose versus Time at Compliance Points

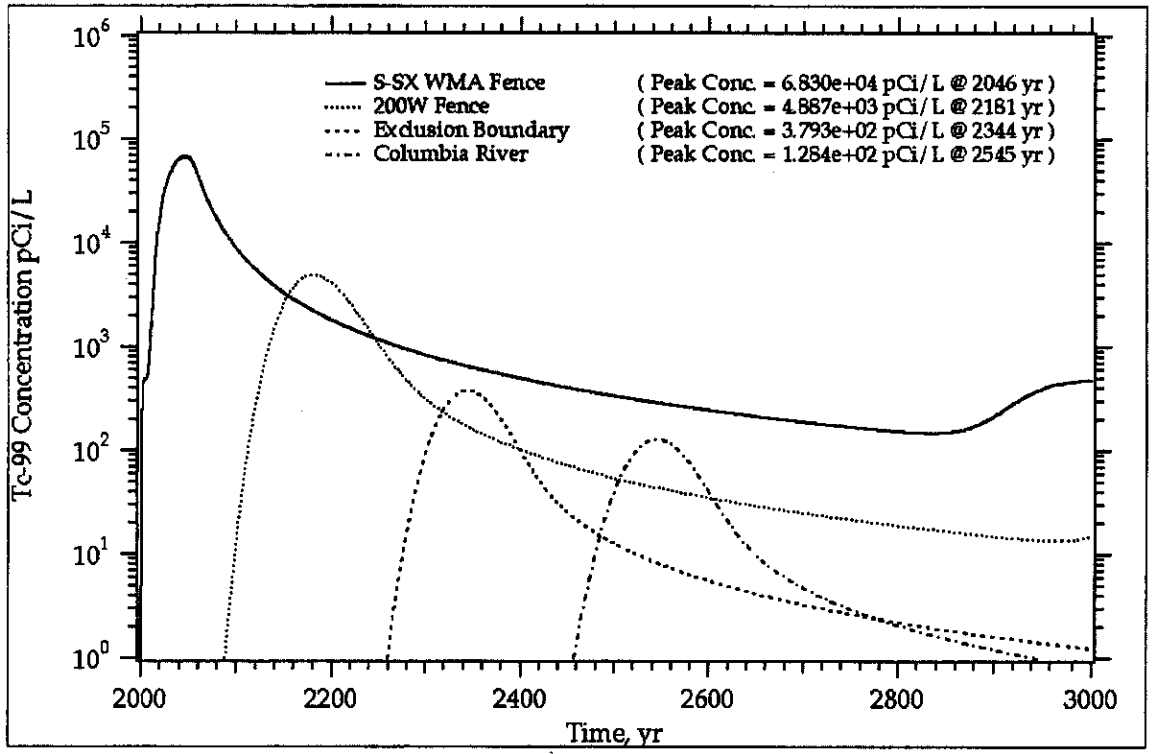


Figure E3.59. Case 4 Area-Weighted Average Cr Concentration versus Time at Compliance Points

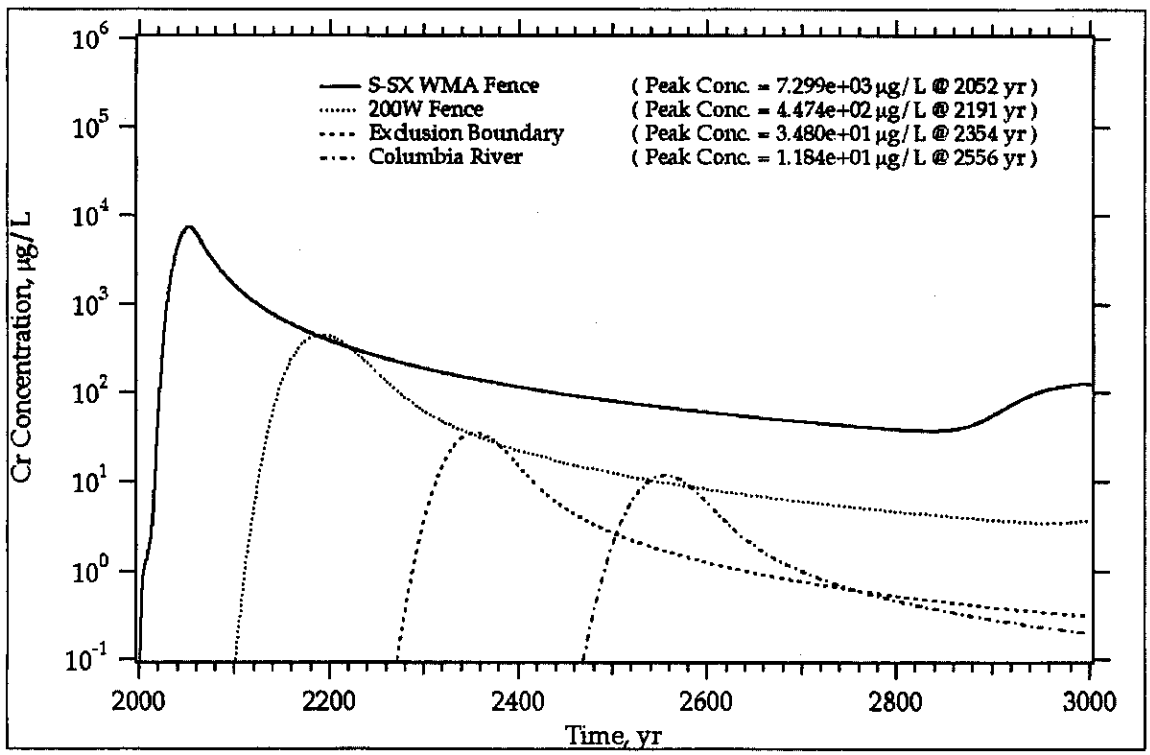
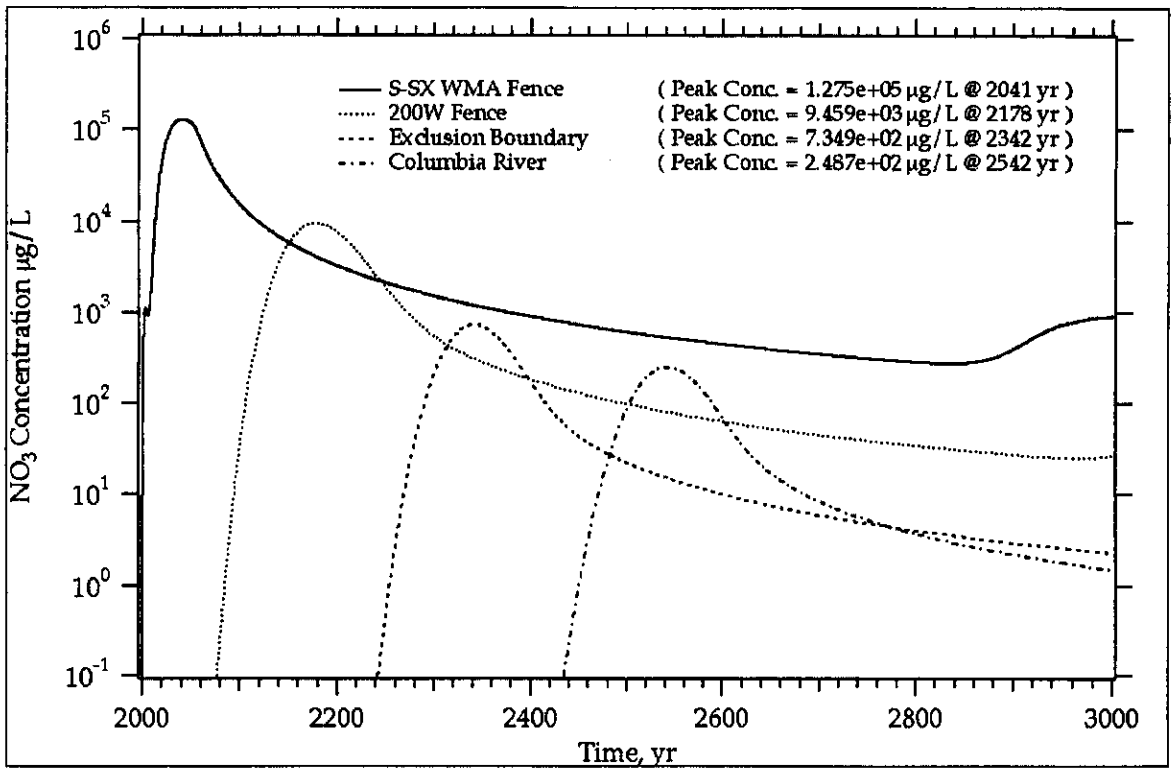


Figure E3.60. Case 4 Area-Weighted Average NO_3 Concentration versus Time at Compliance Points



E3.5.0 CASE 5: NONUNIFORM INVENTORY DISTRIBUTION AND NO BARRIER

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only, no water-line leak, no barrier until closure in 2040, and a higher distribution of inventory at a few locations (e.g., a few nodes, with a high concentration, either at the same depth or at different locations).

Figure E3.61. Case 5 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

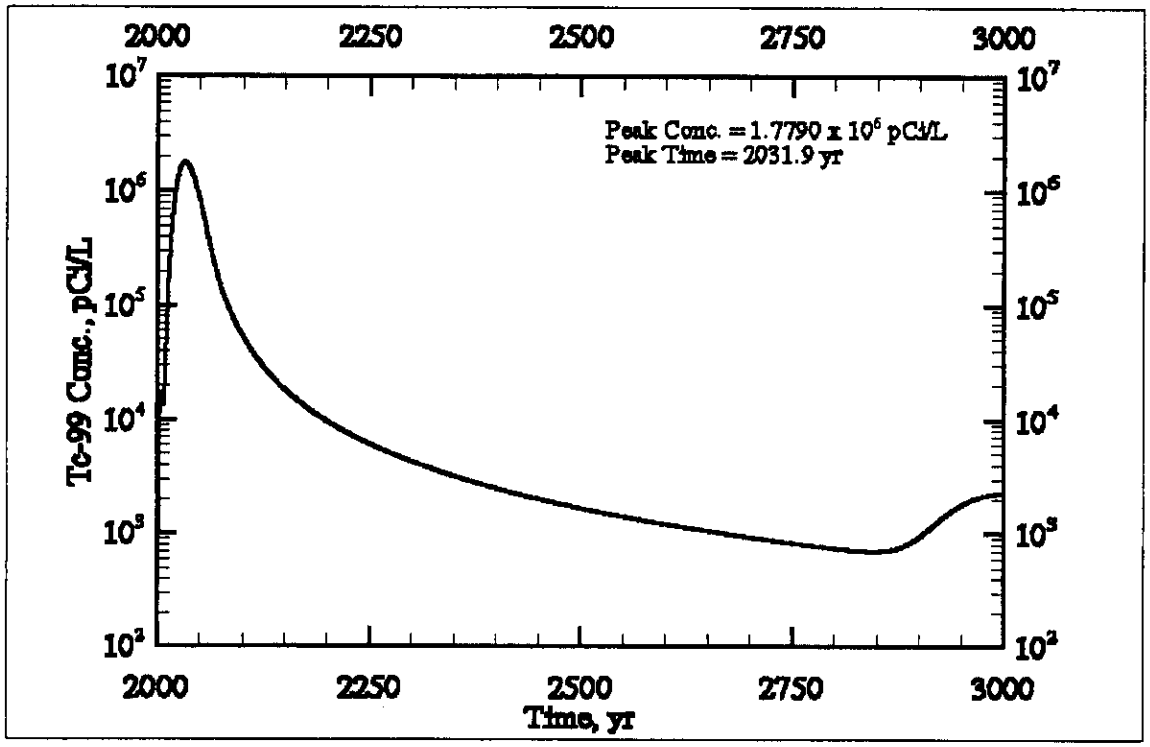


Figure E3.62. Case 5 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

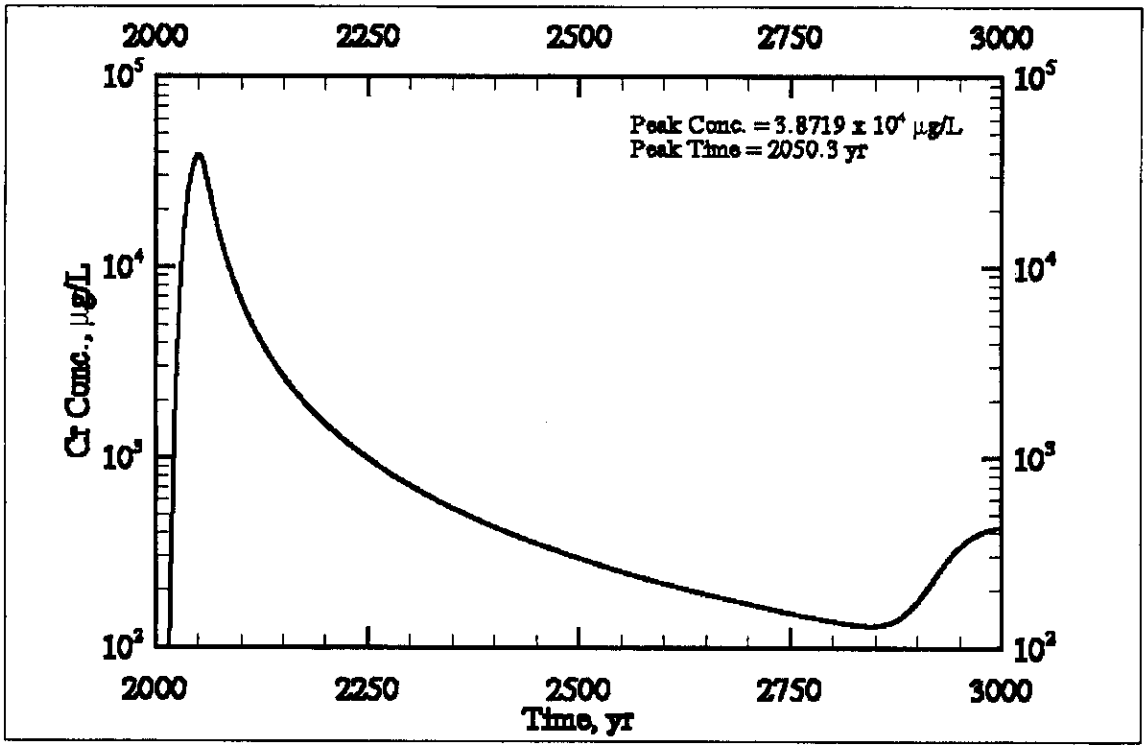


Figure E3.63. Case 5 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

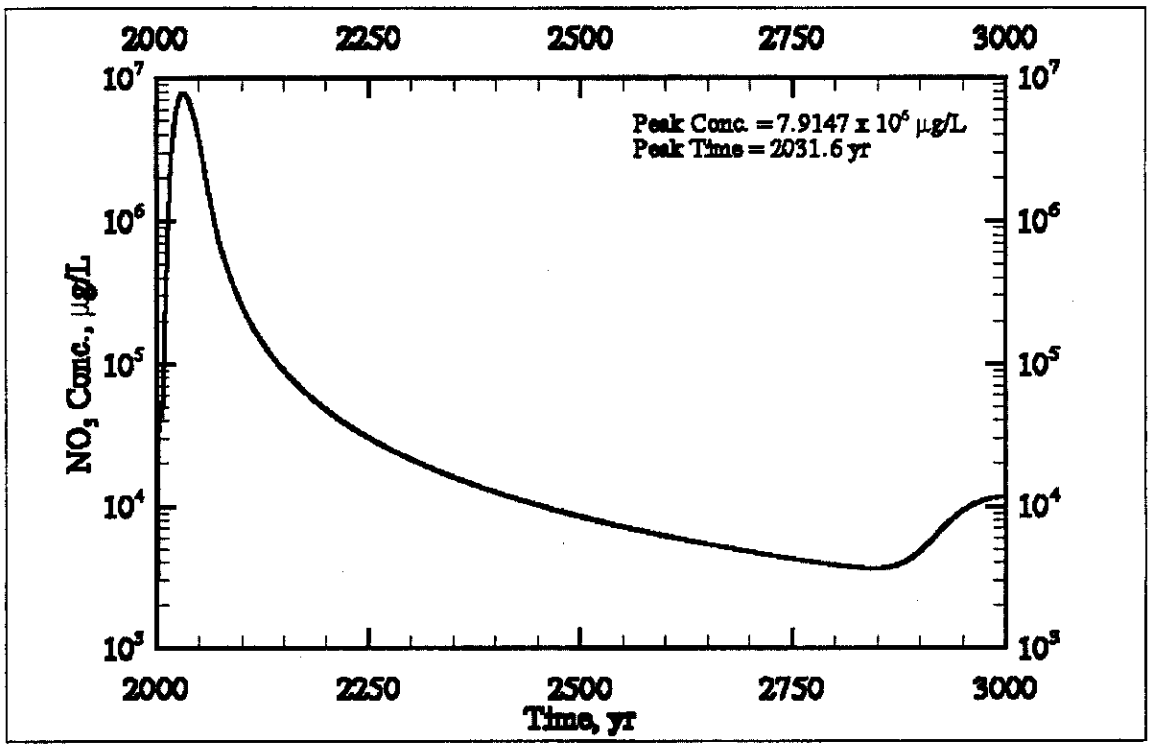


Figure E3.64. Case 5 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

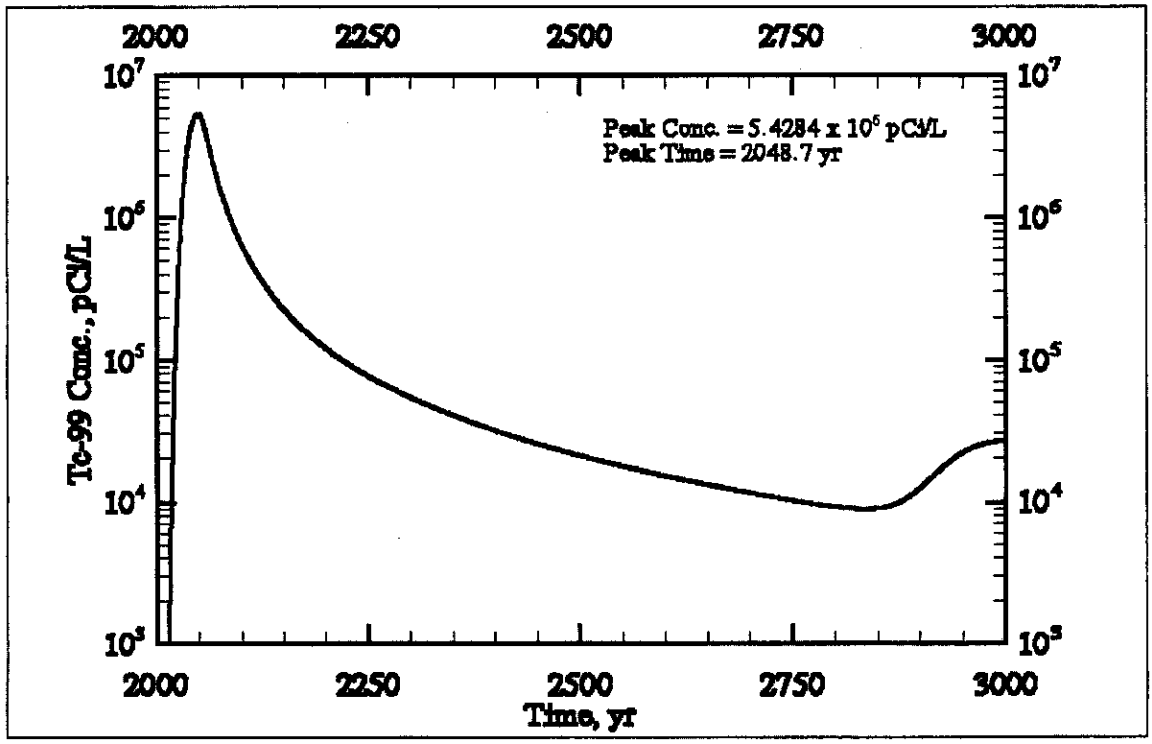


Figure E3.65. Case 5 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

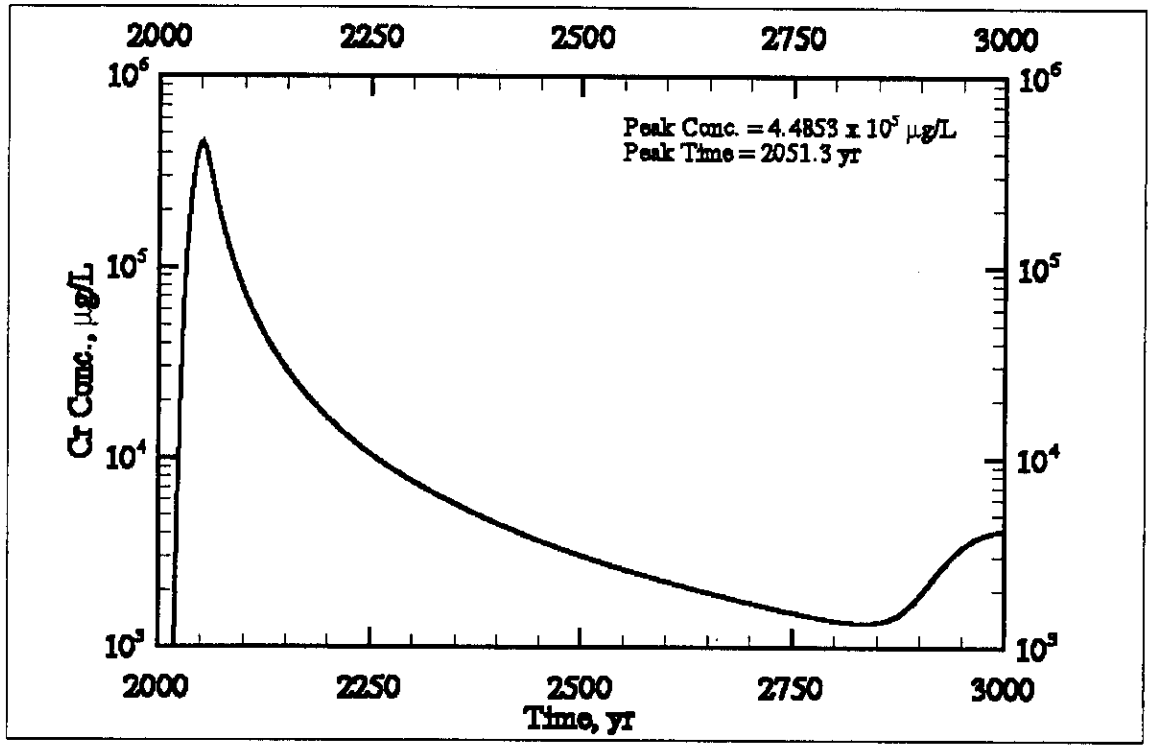


Figure E3.66. Case 5 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

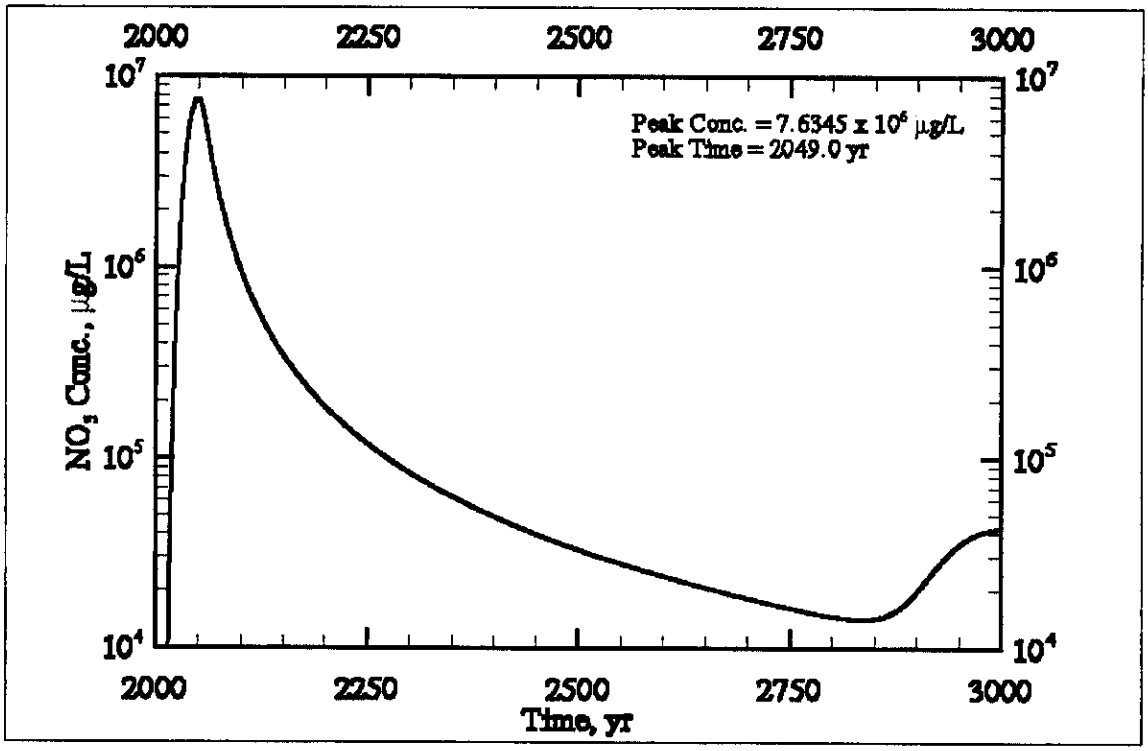


Figure E3.67. Case 5 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

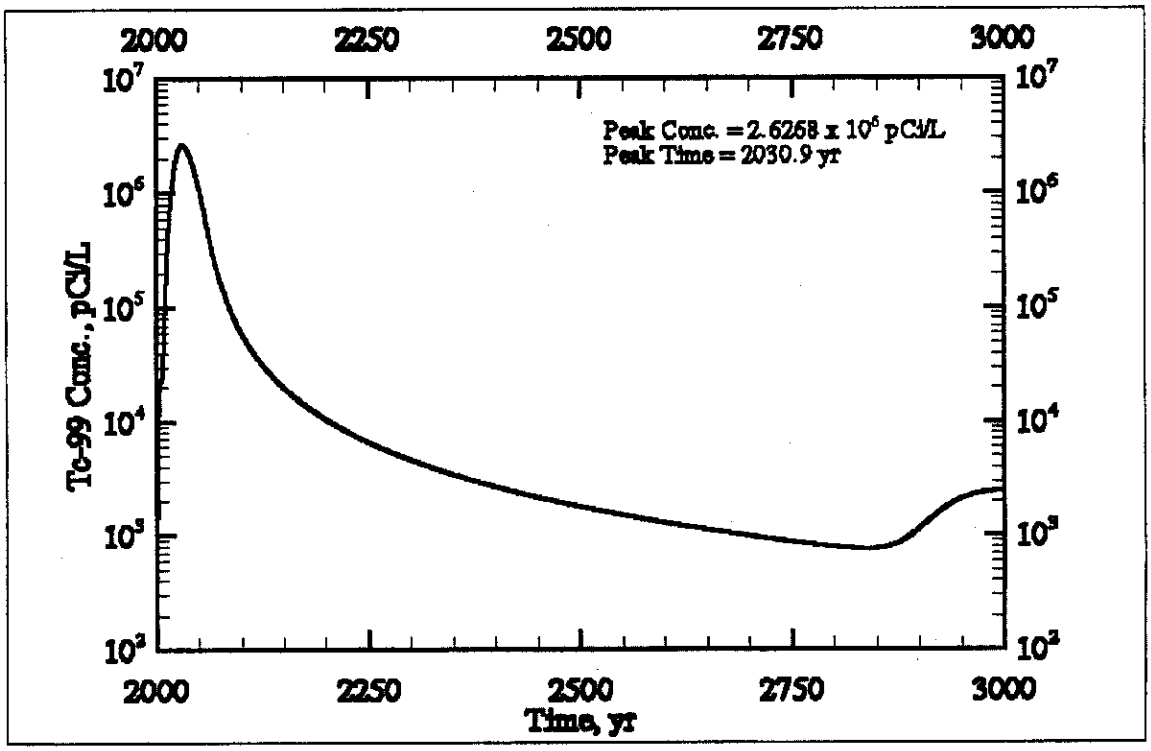


Figure E3.68. Case 5 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

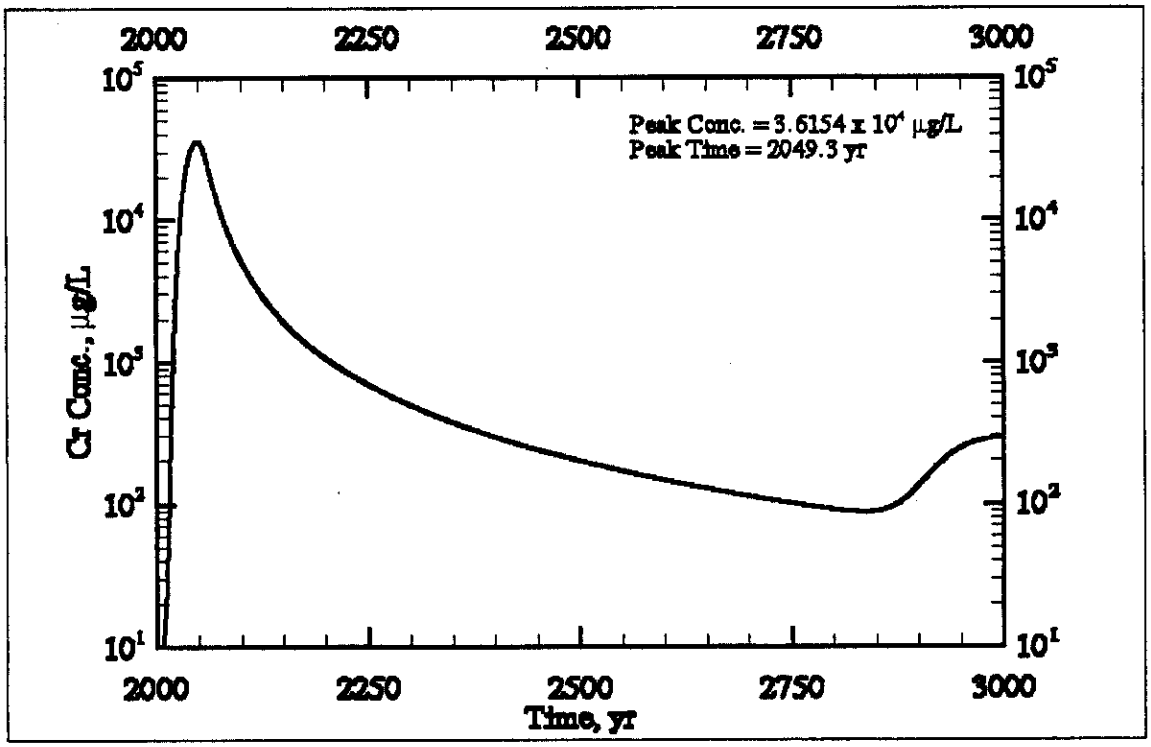


Figure E3.69. Case 5 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

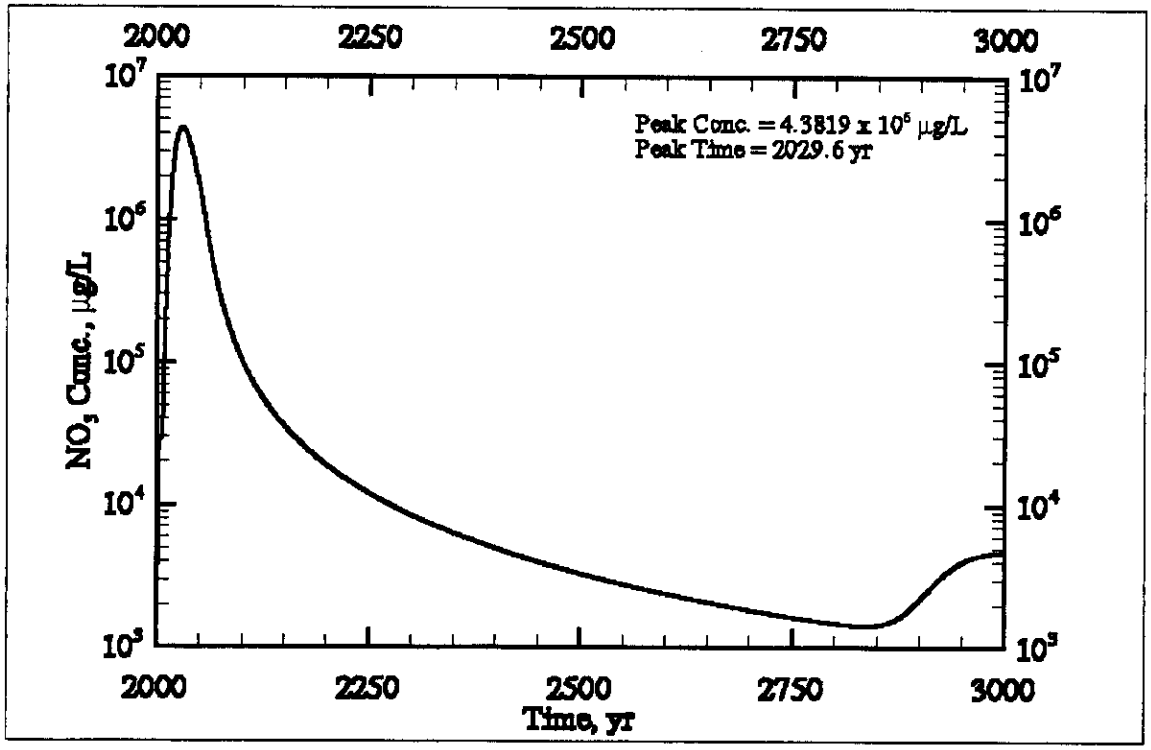


Figure E3.70. Case 5 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

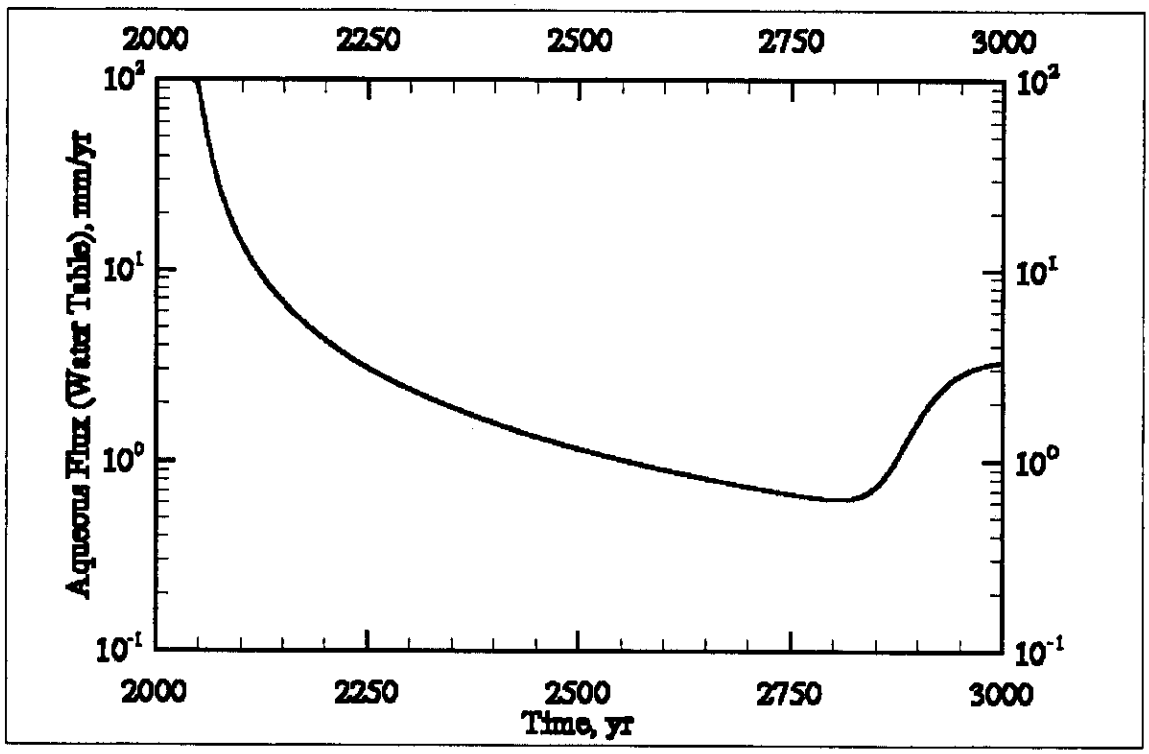


Figure E3.71. Case 5 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

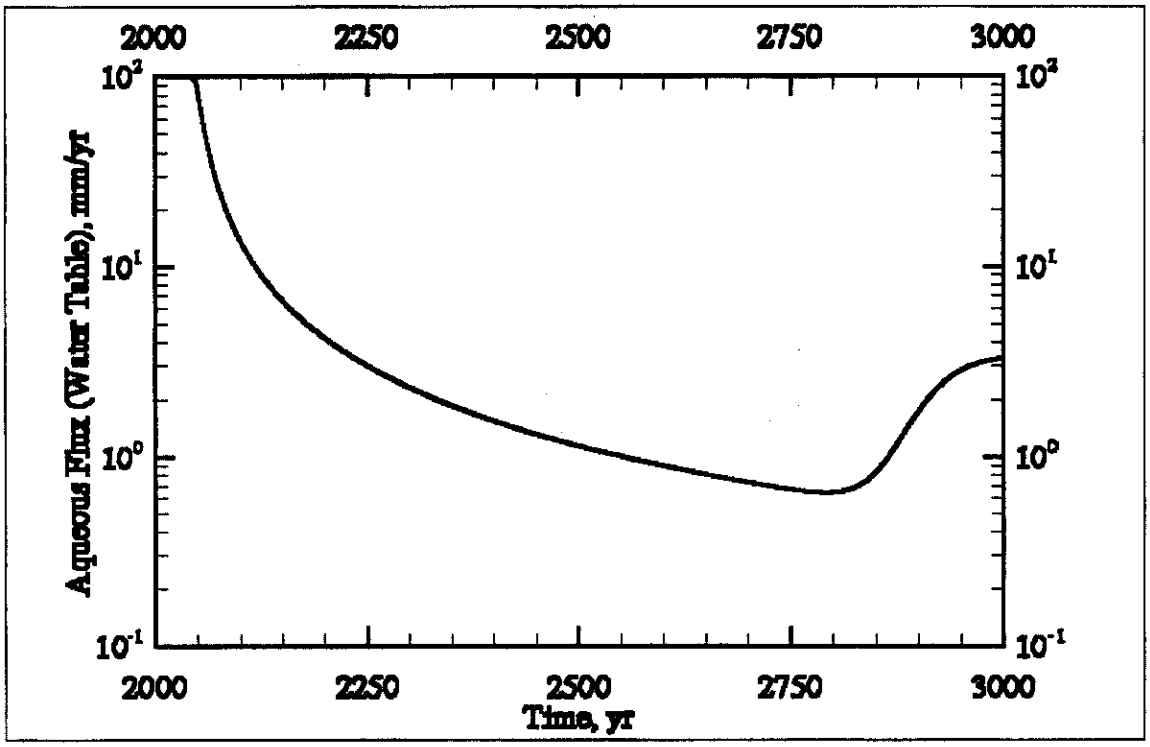


Figure E3.72. Case 5 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

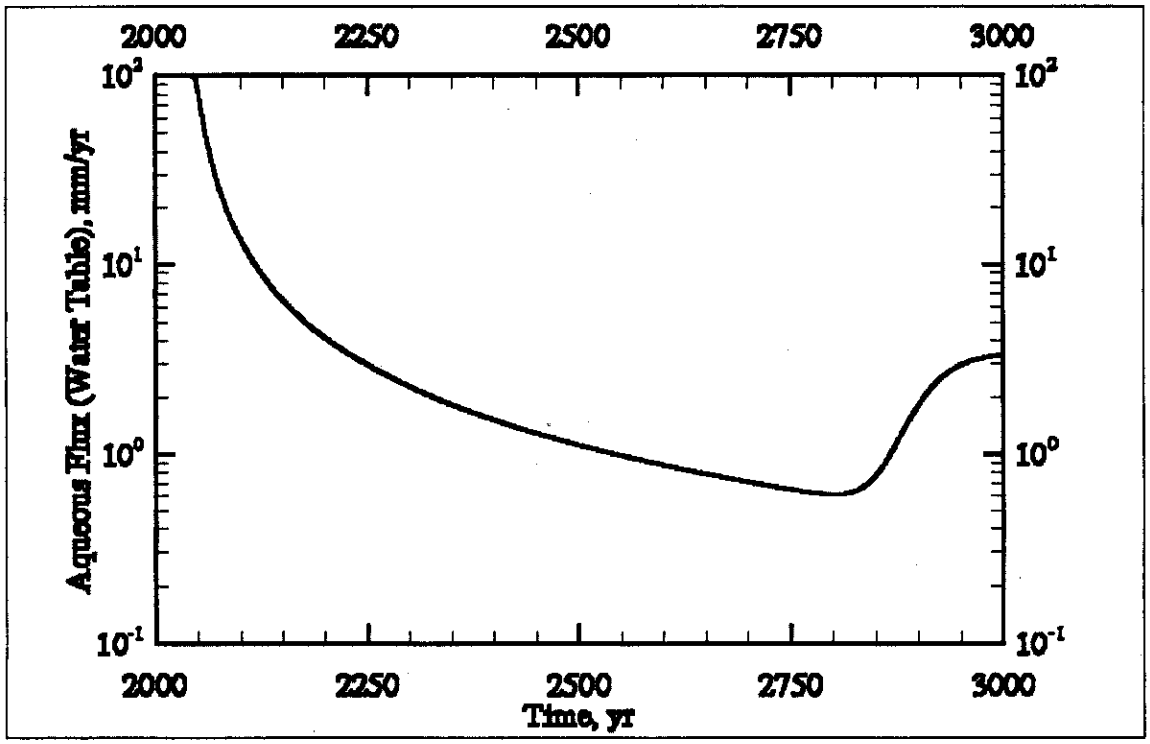


Figure E3.73. Case 5 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

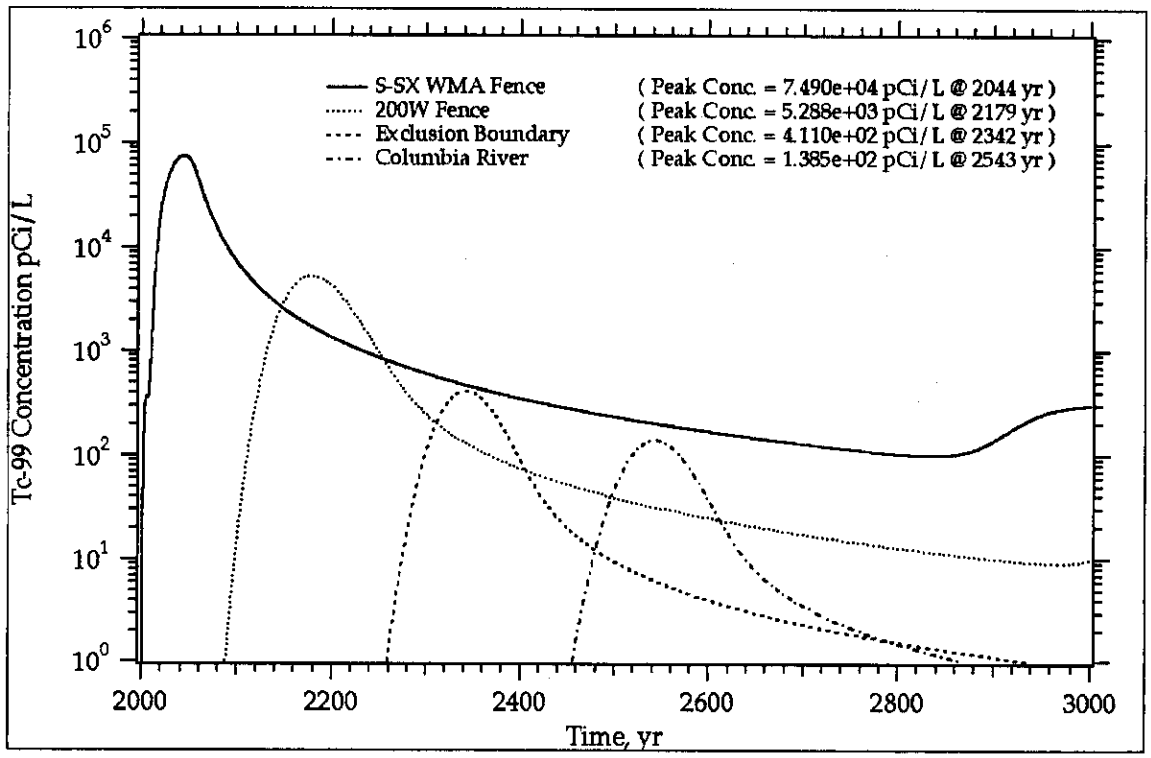


Figure E3.74. Case 5 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

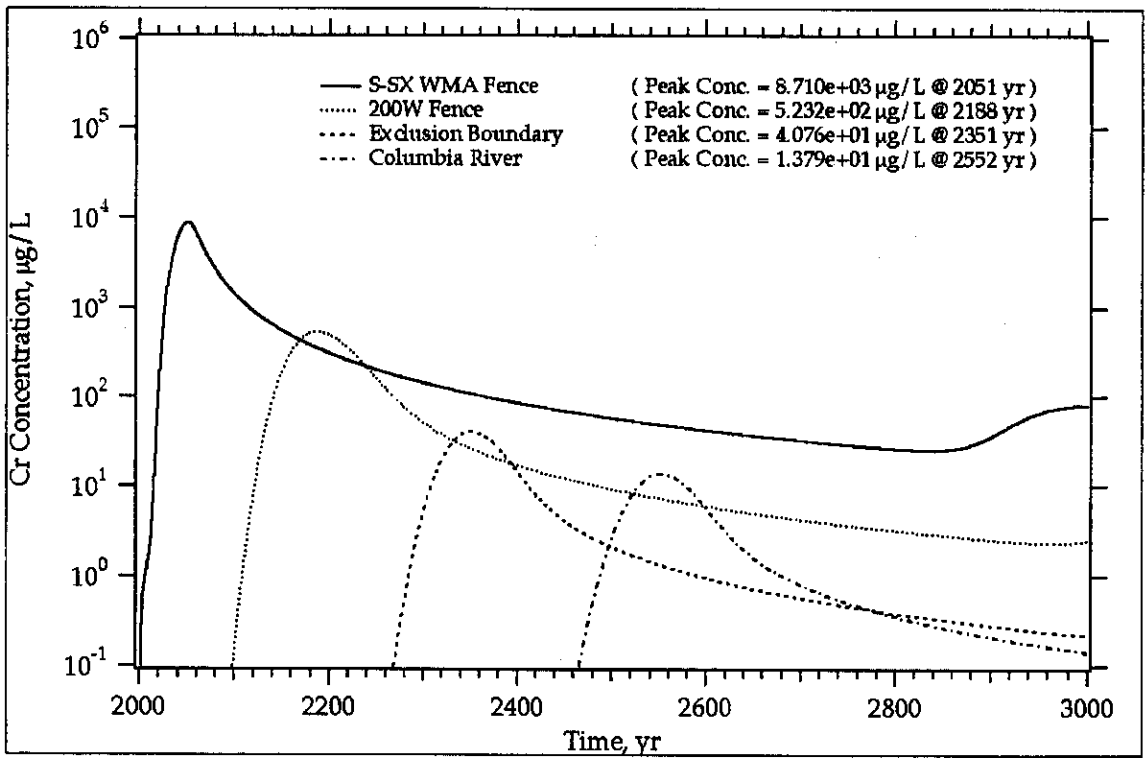
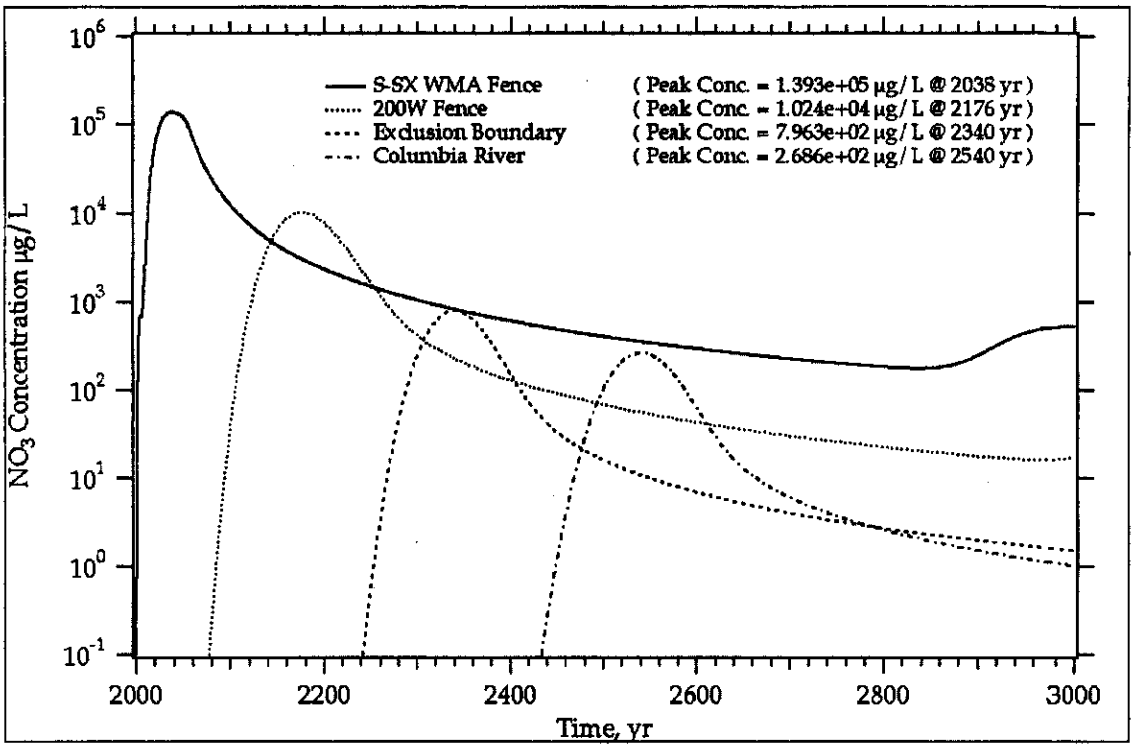


Figure E3.75. Case 5 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.6.0 CASE 6: NONUNIFORM INVENTORY DISTRIBUTION AND BARRIER

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering barrier infiltration (interim barrier replaced at closure in 2040), no water-line leak, and a higher distribution of inventory at a few locations (e.g., a few nodes, with a high concentration, either at the same depth or at different locations).

Figure E3.76. Case 6 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

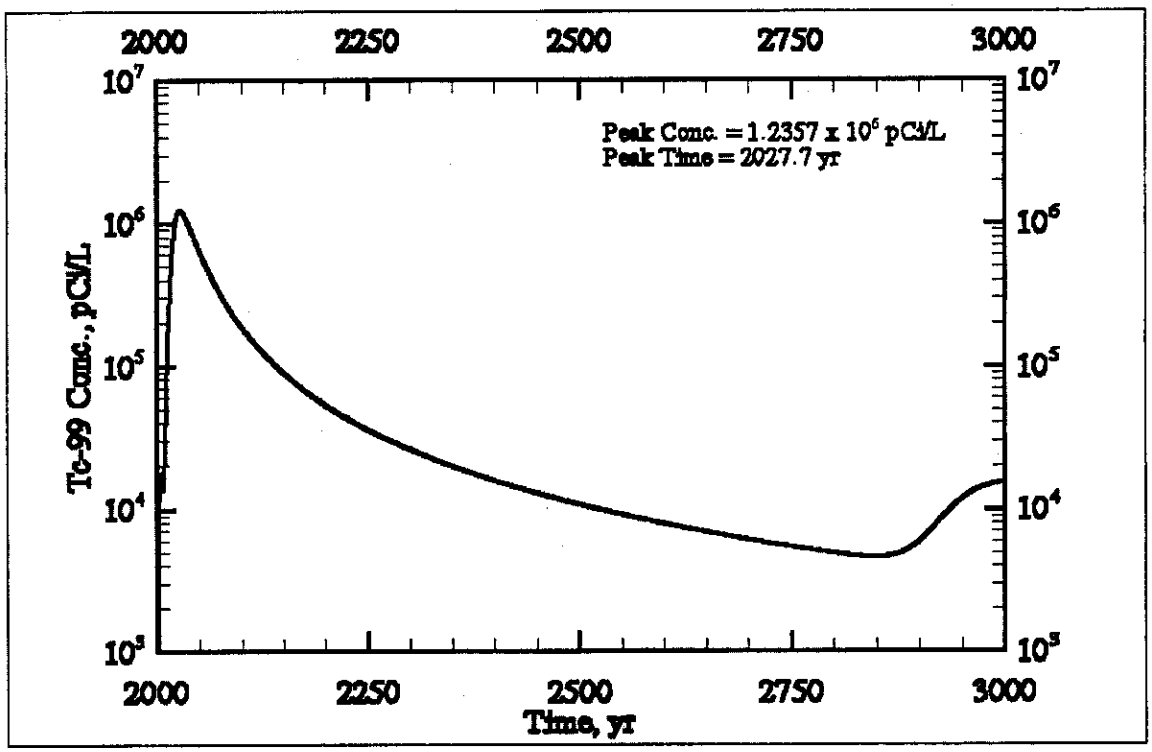


Figure E3.77. Case 6 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

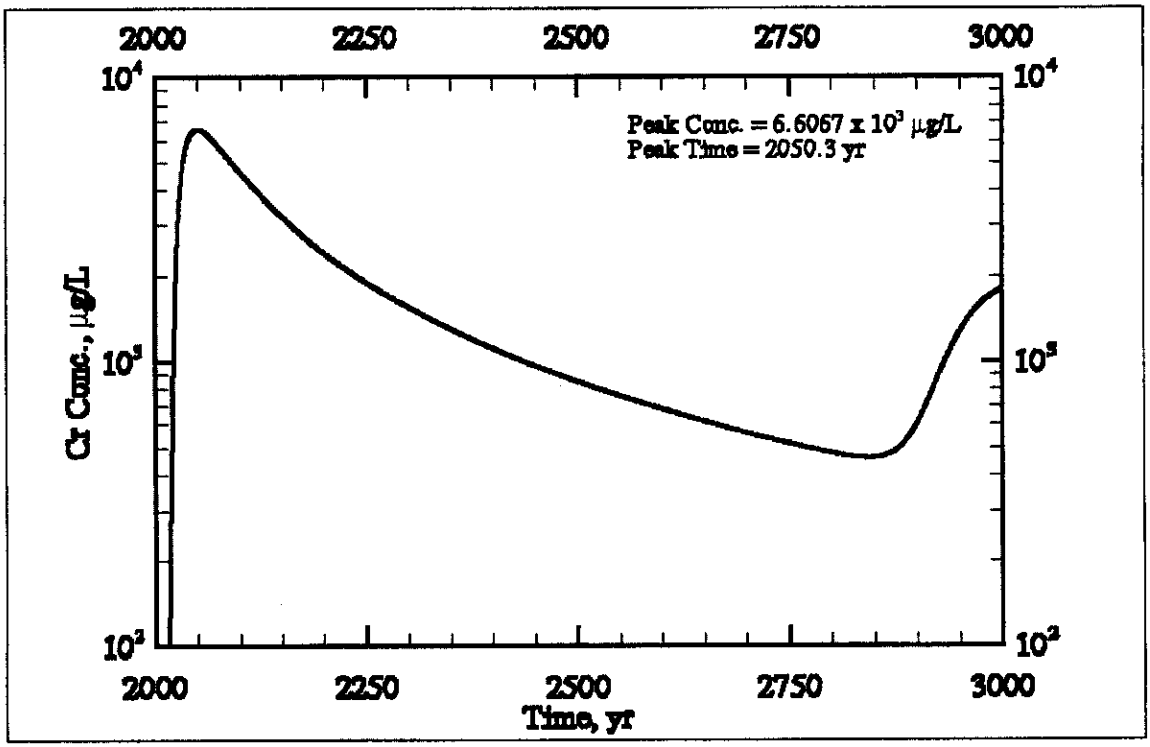


Figure E3.78. Case 6 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

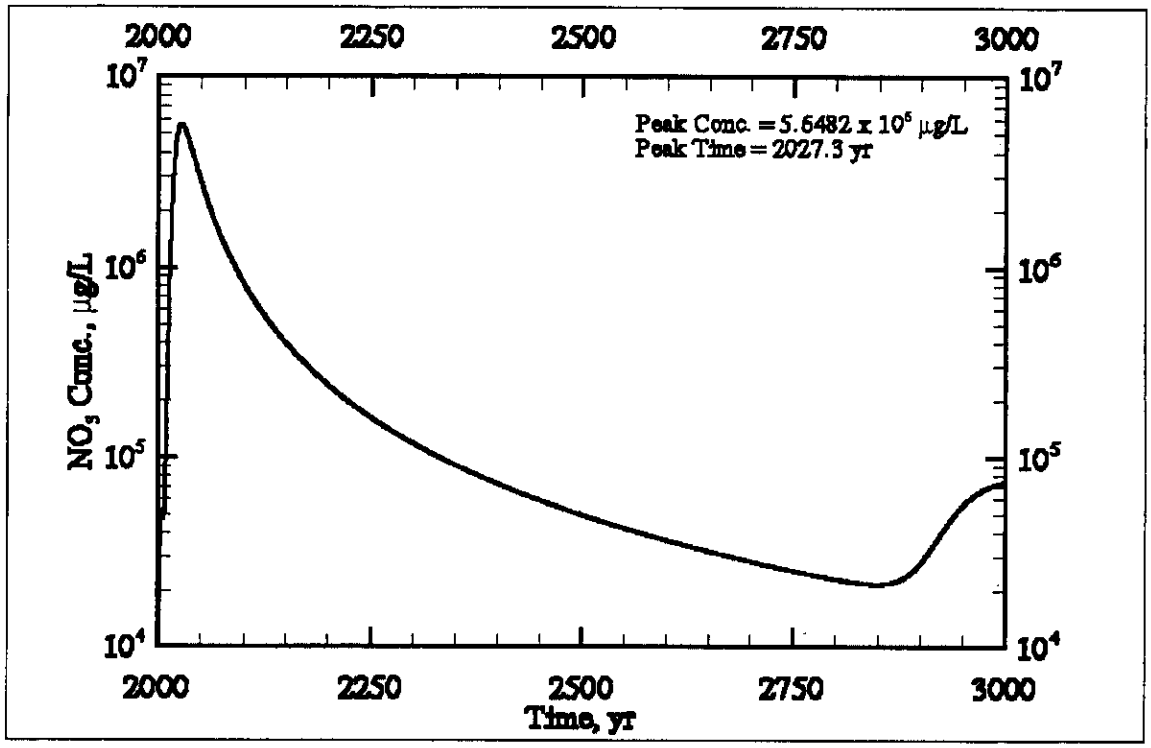


Figure E3.79. Case 6 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

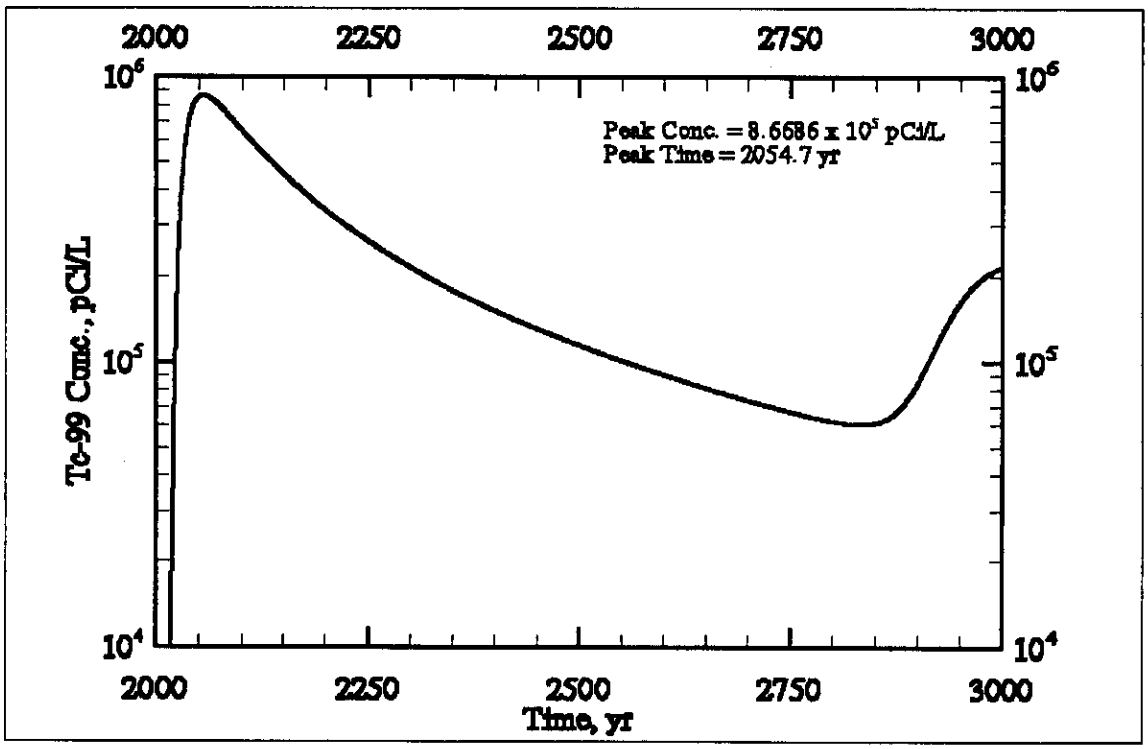


Figure E3.80. Case 6 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

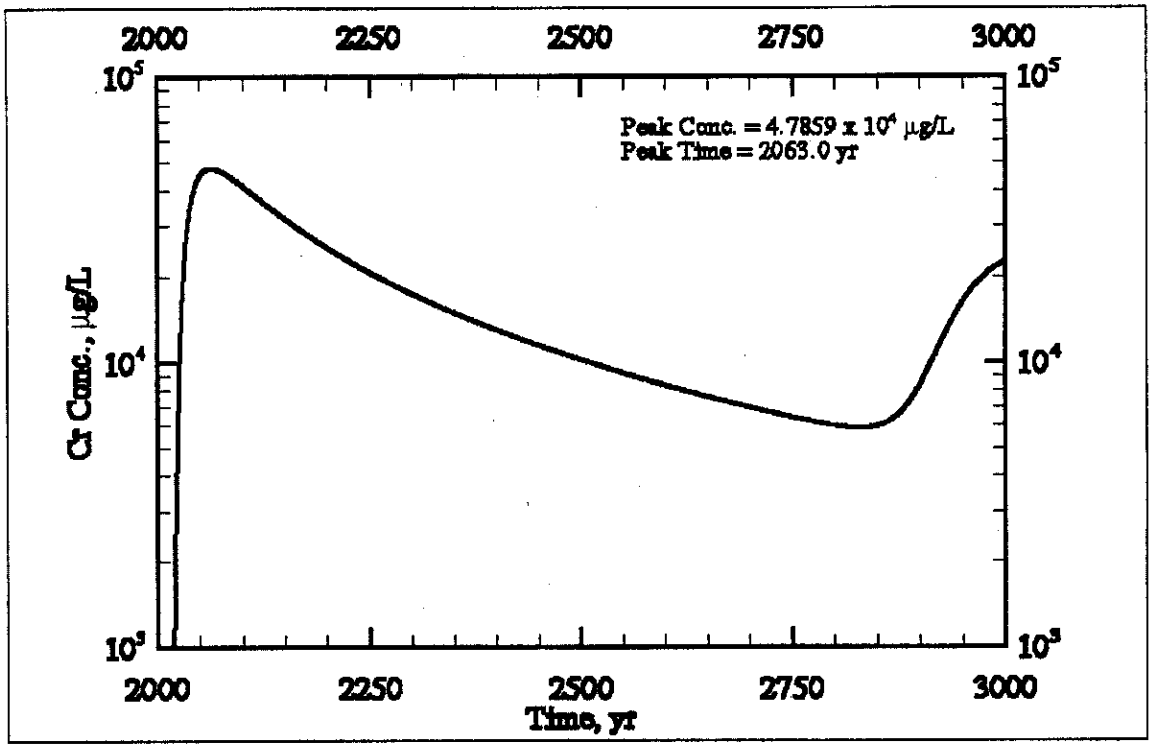


Figure E3.81. Case 6 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

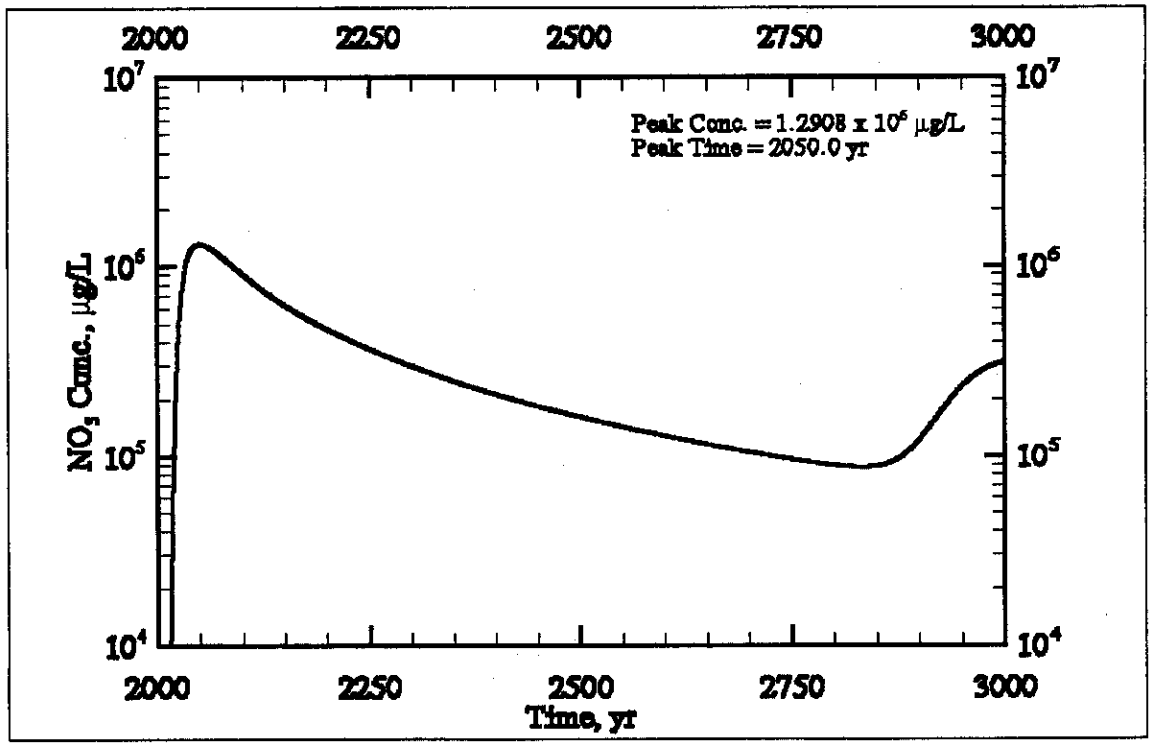


Figure E3.82. Case 6 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

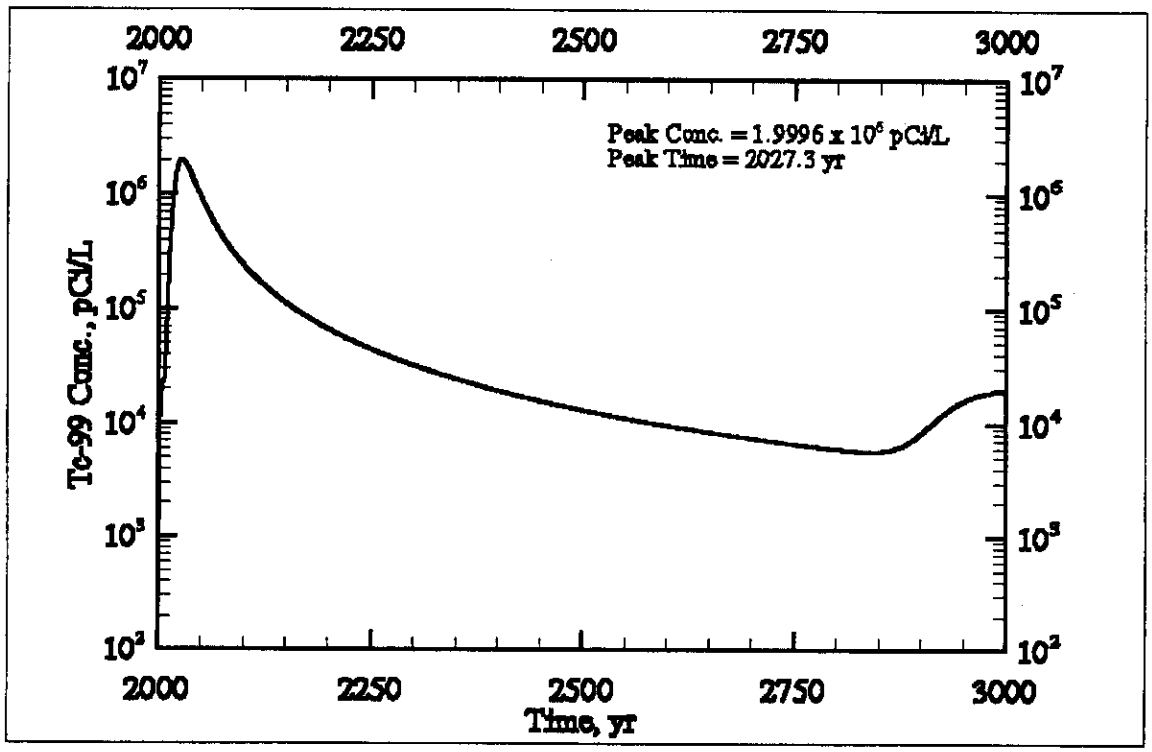


Figure E3.83. Case 6 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

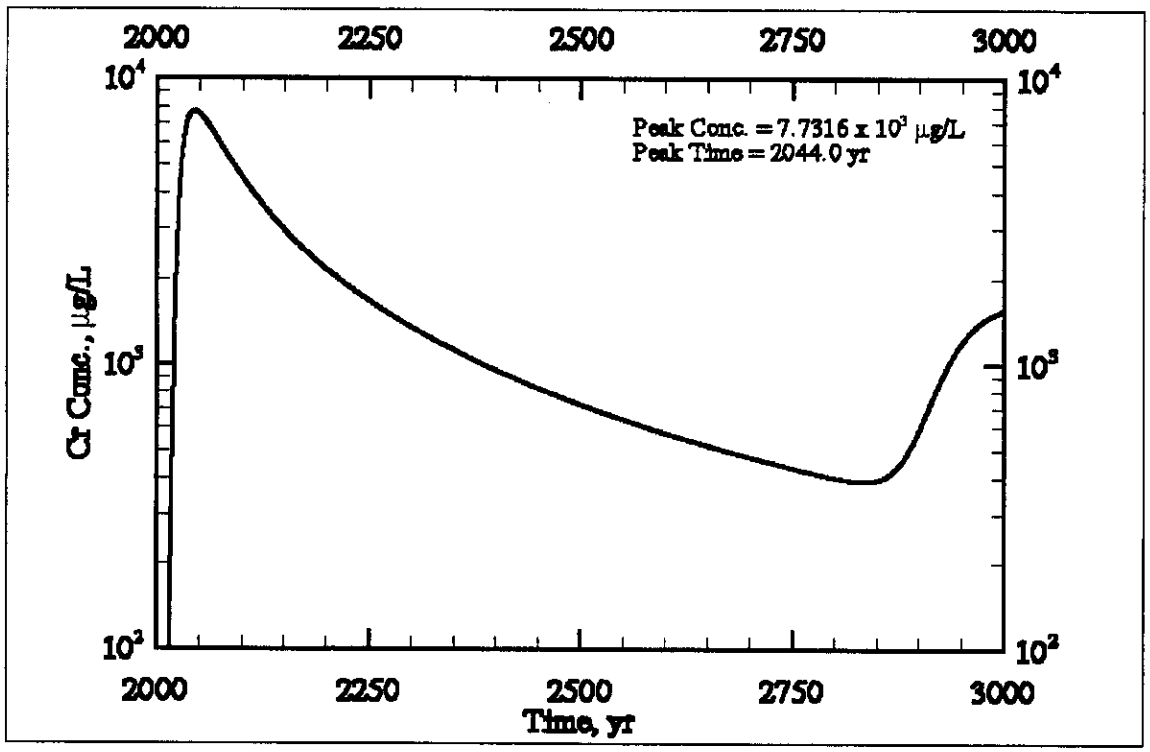


Figure E3.84. Case 6 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

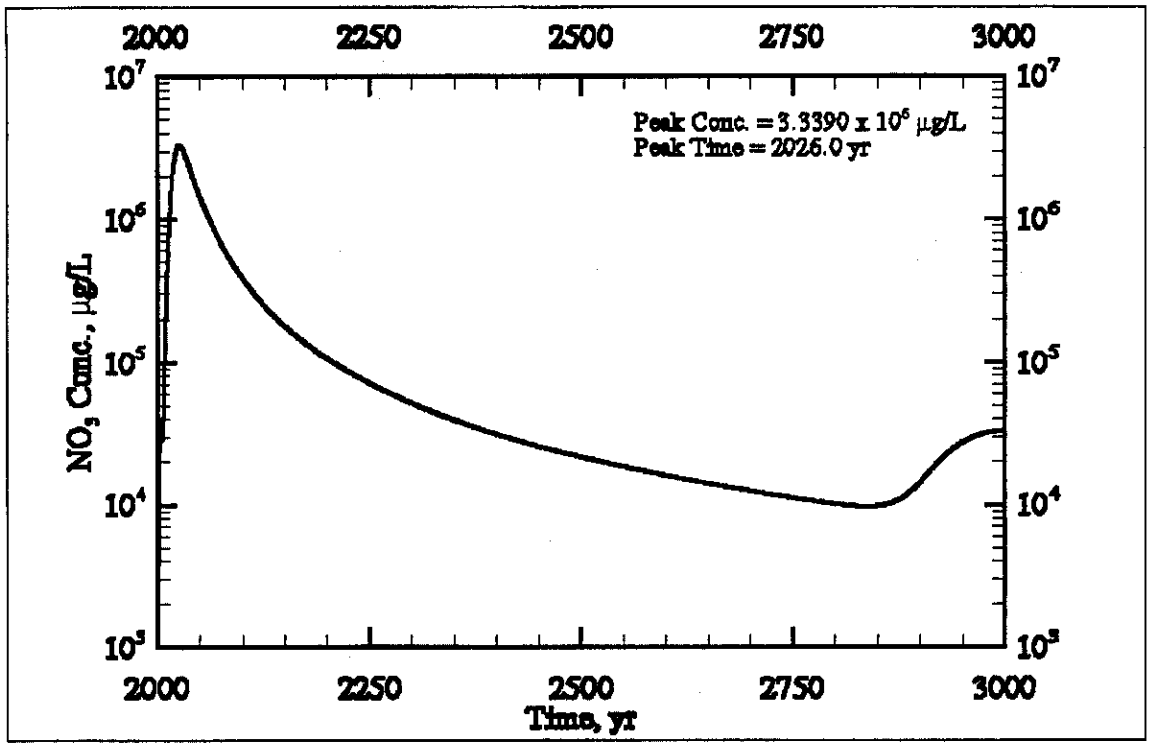


Figure E3.85. Case 6 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

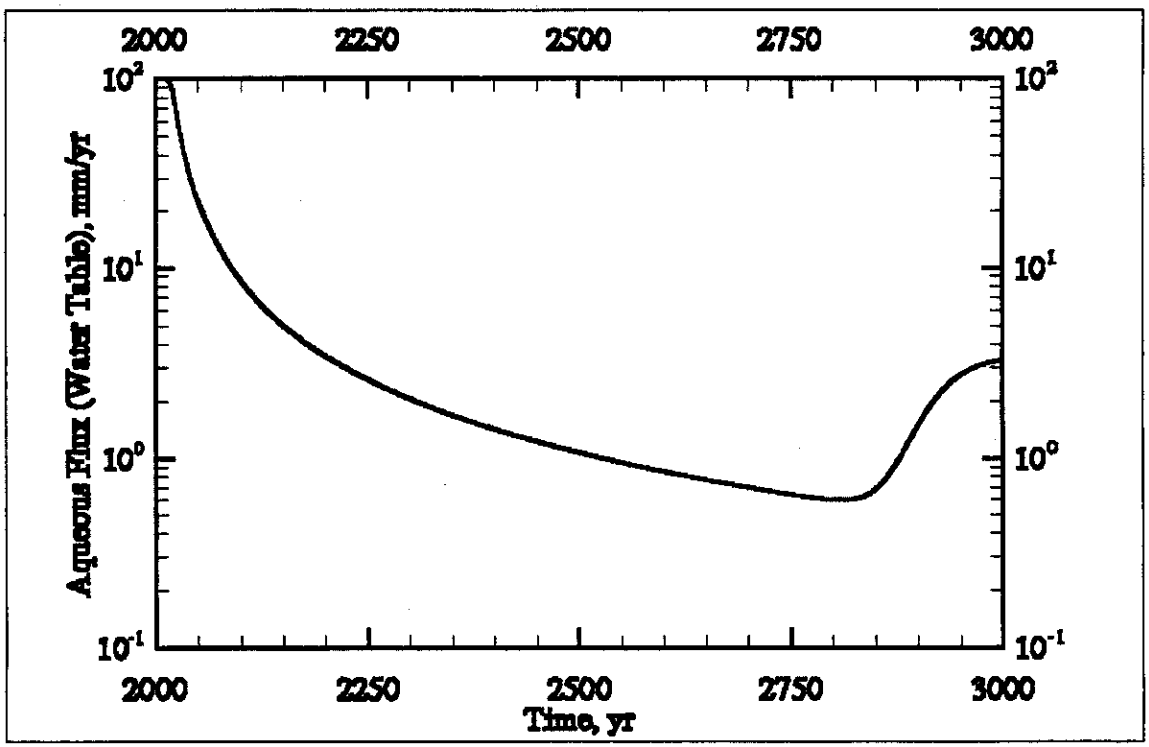


Figure E3.86. Case 6 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

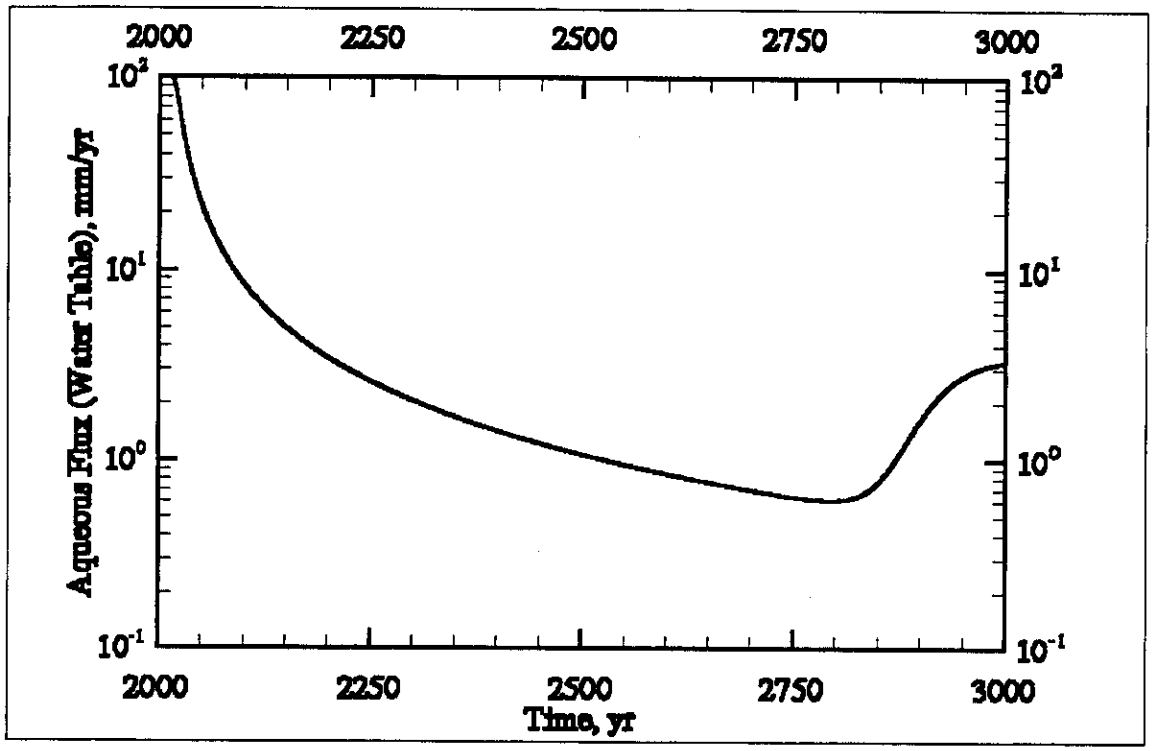


Figure E3.87. Case 6 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

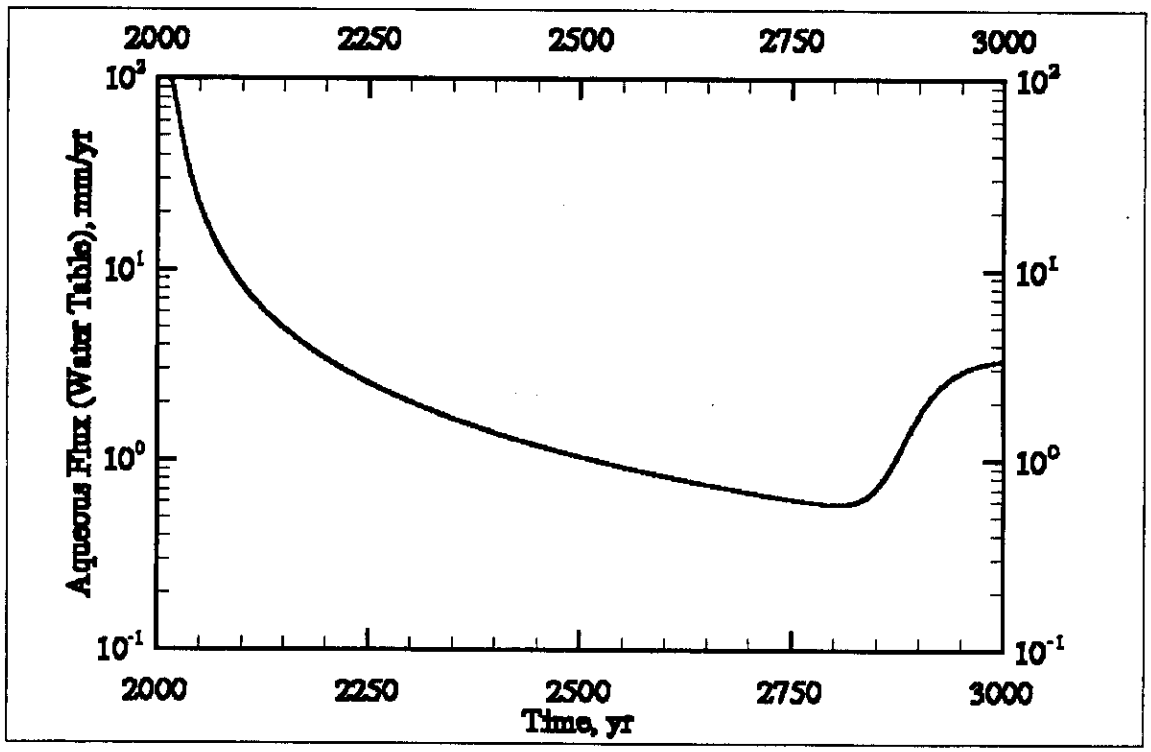


Figure E3.88. Case 6 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

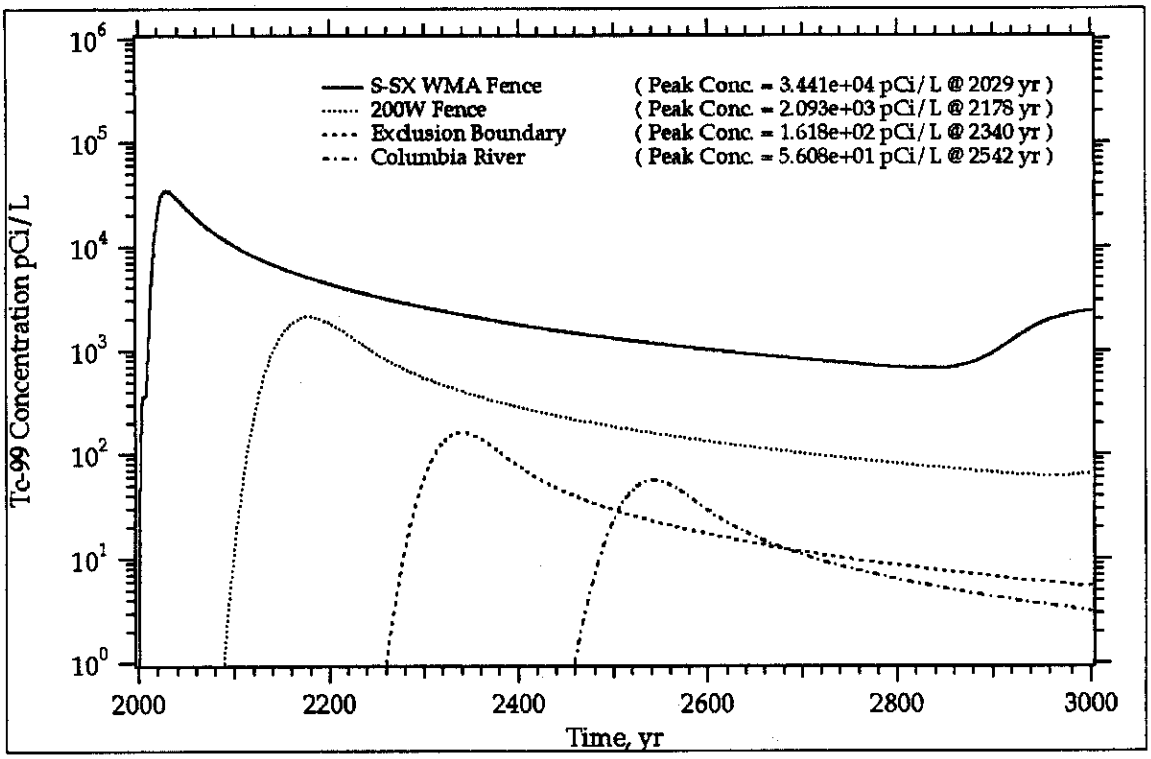


Figure E3.89. Case 6 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

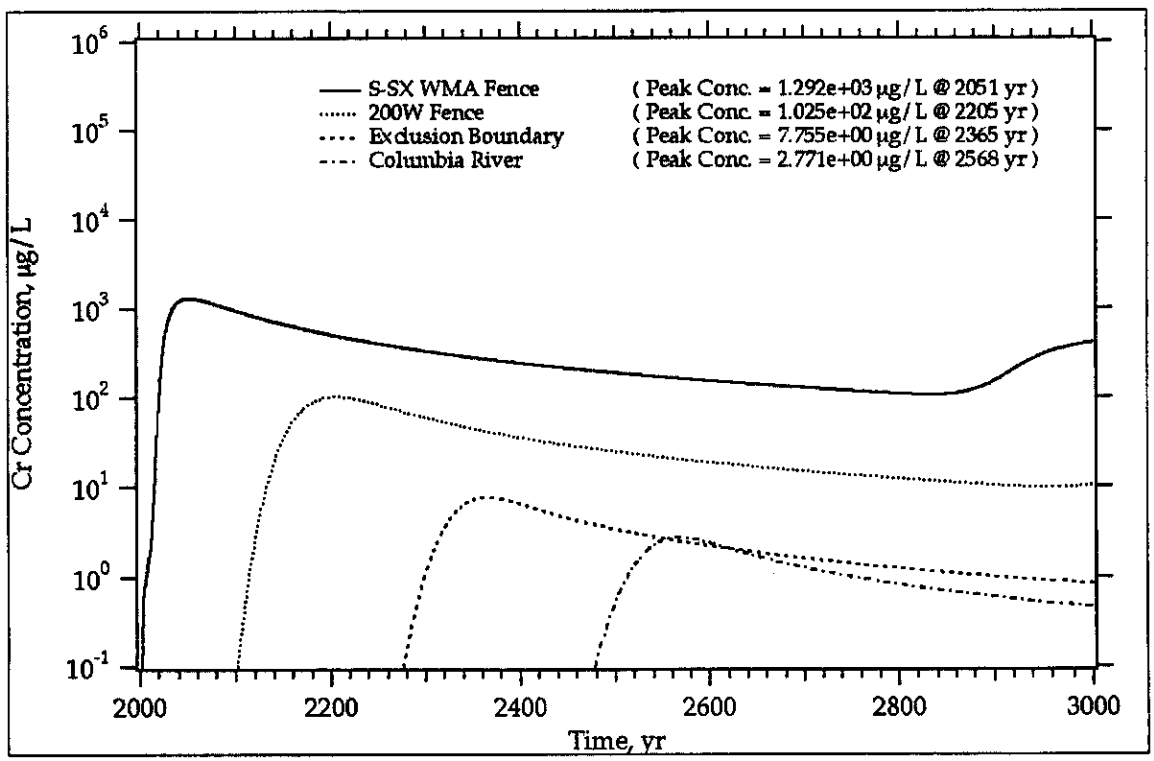
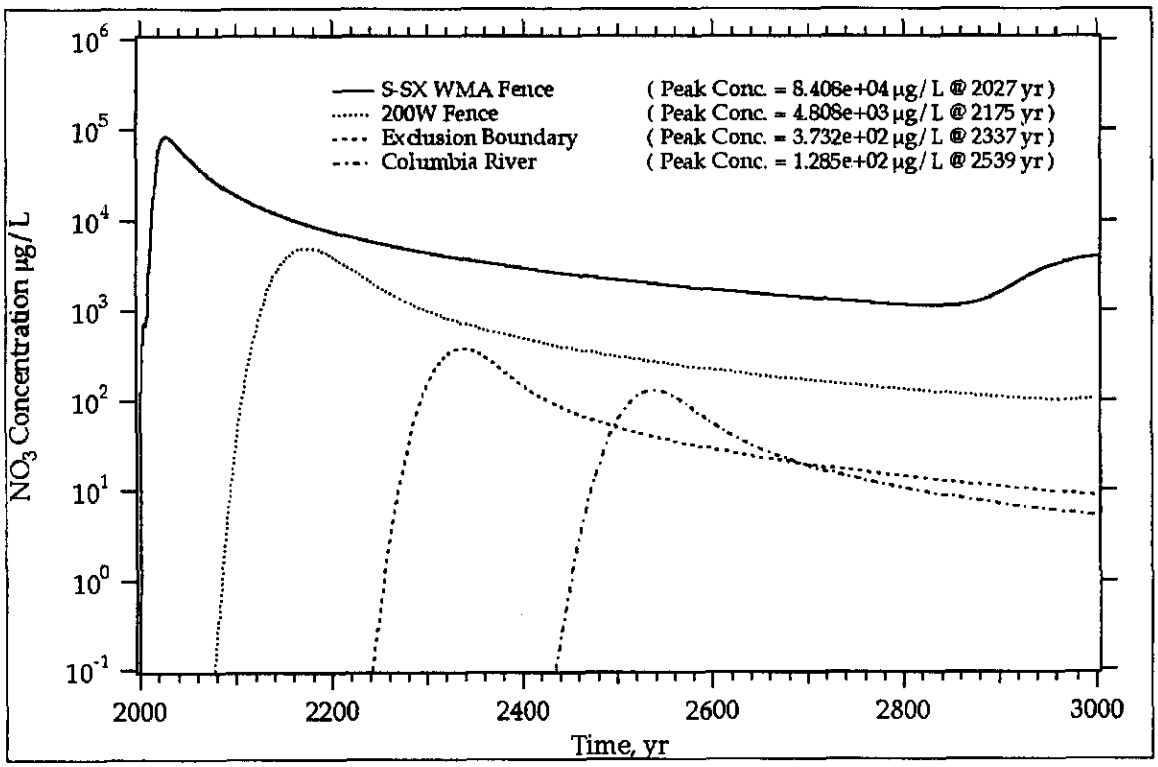


Figure E3.90. Case 6 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.7.0 CASE 7: LOCATION OF INVENTORY DISTRIBUTION AND NO BARRIER

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only, no water-line leak, no barrier until closure in 2040, and concentrated distribution of inventory location close to the water table.

Figure E3.91. Case 7 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

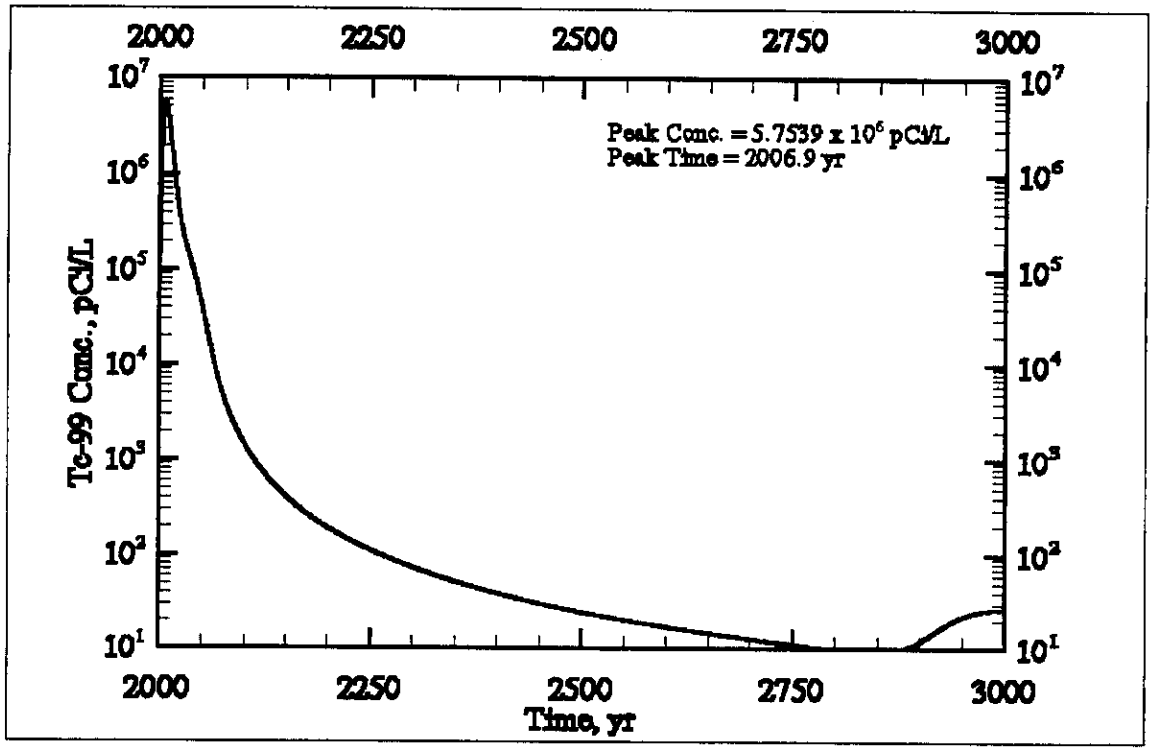


Figure E3.92. Case 7 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

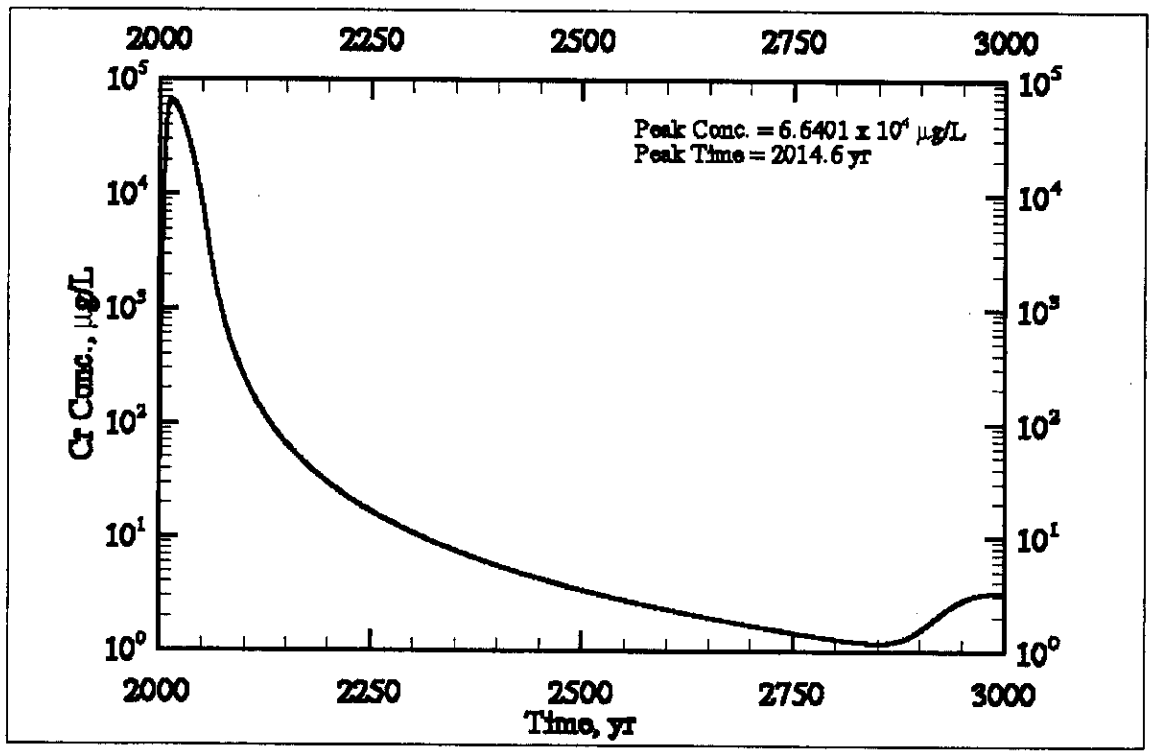


Figure E3.93. Case 7 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

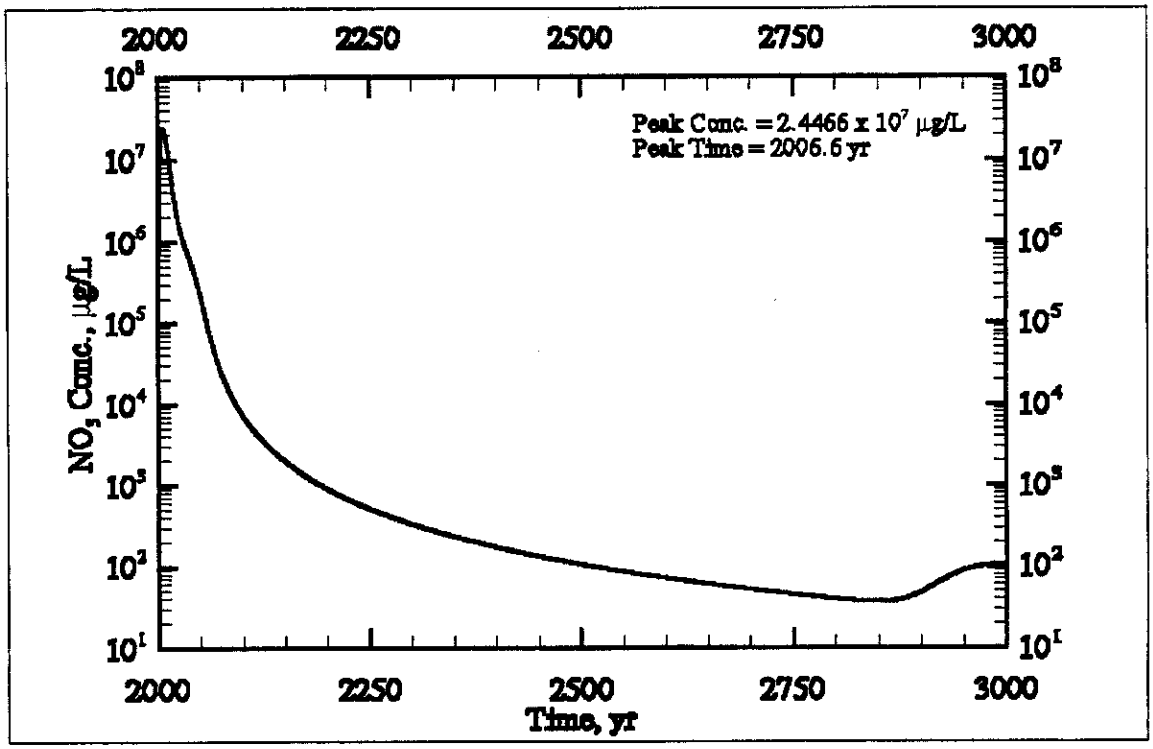


Figure E3.94. Case 7 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

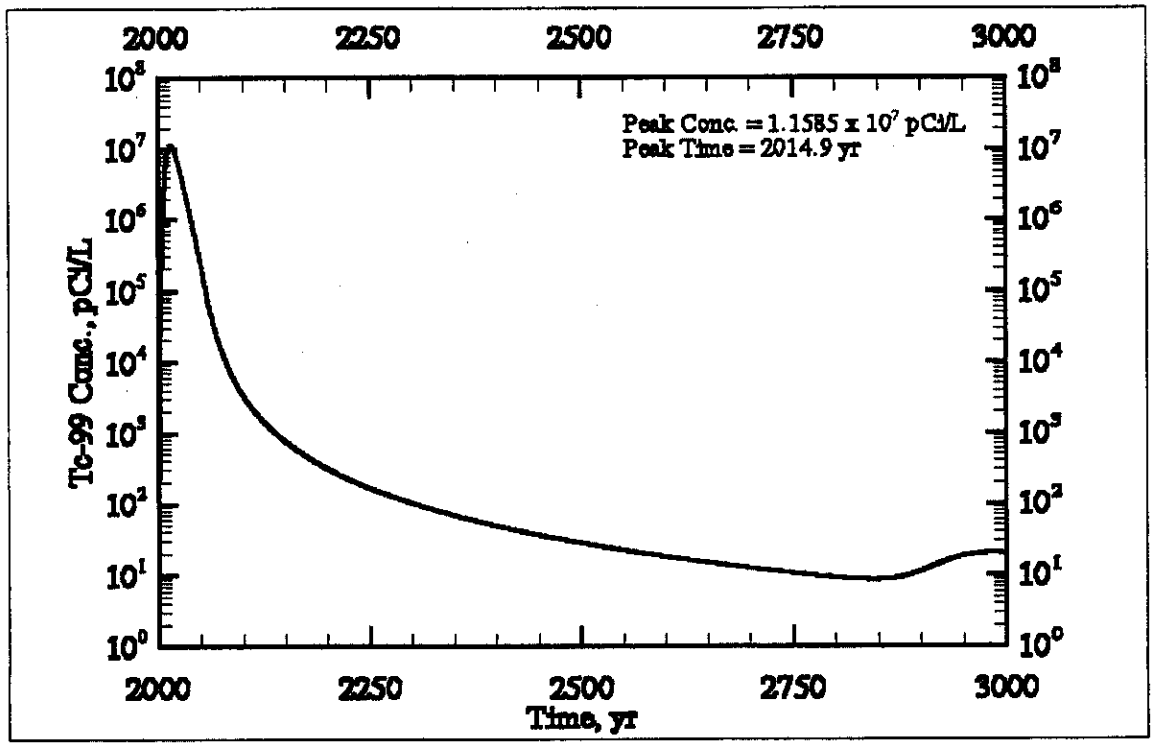


Figure E3.95. Case 7 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

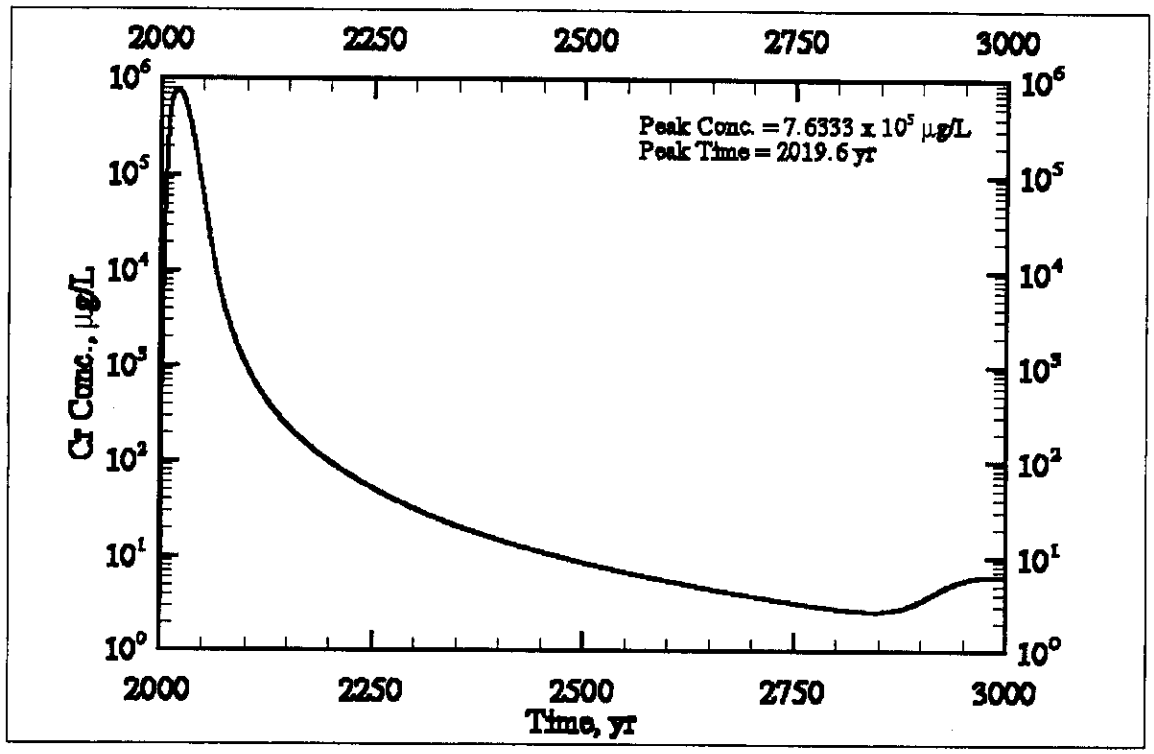


Figure E3.96. Case 7 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

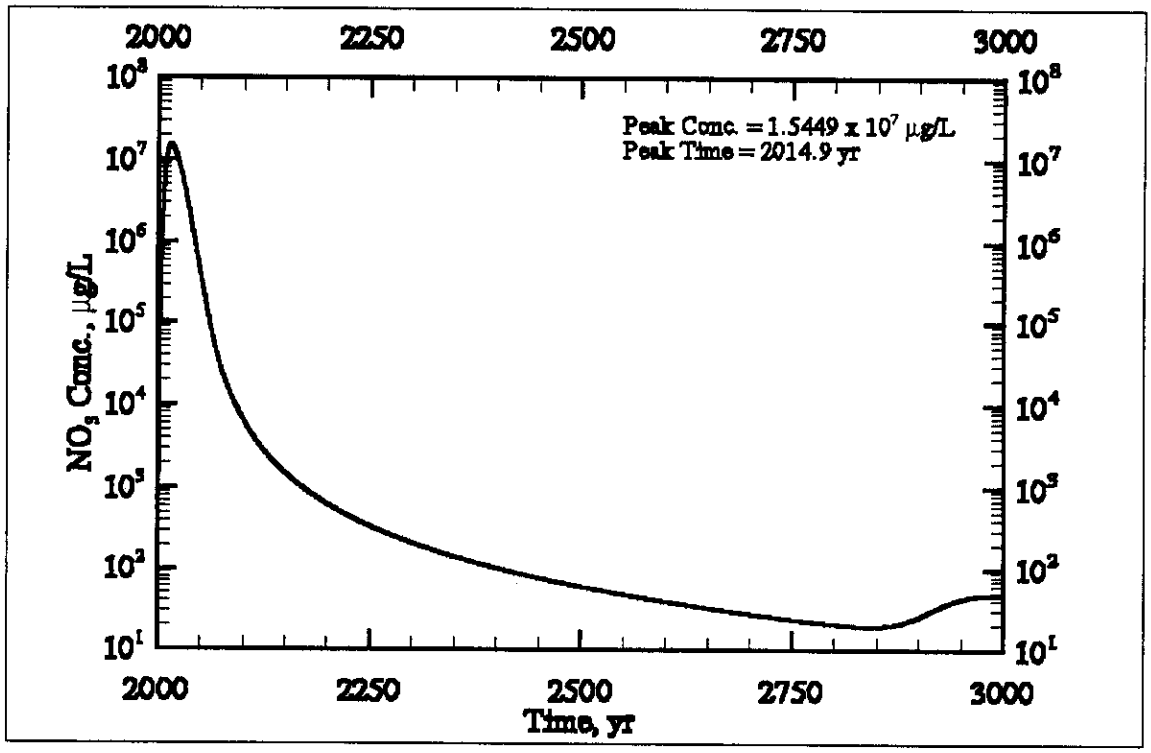


Figure E3.97. Case 7 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

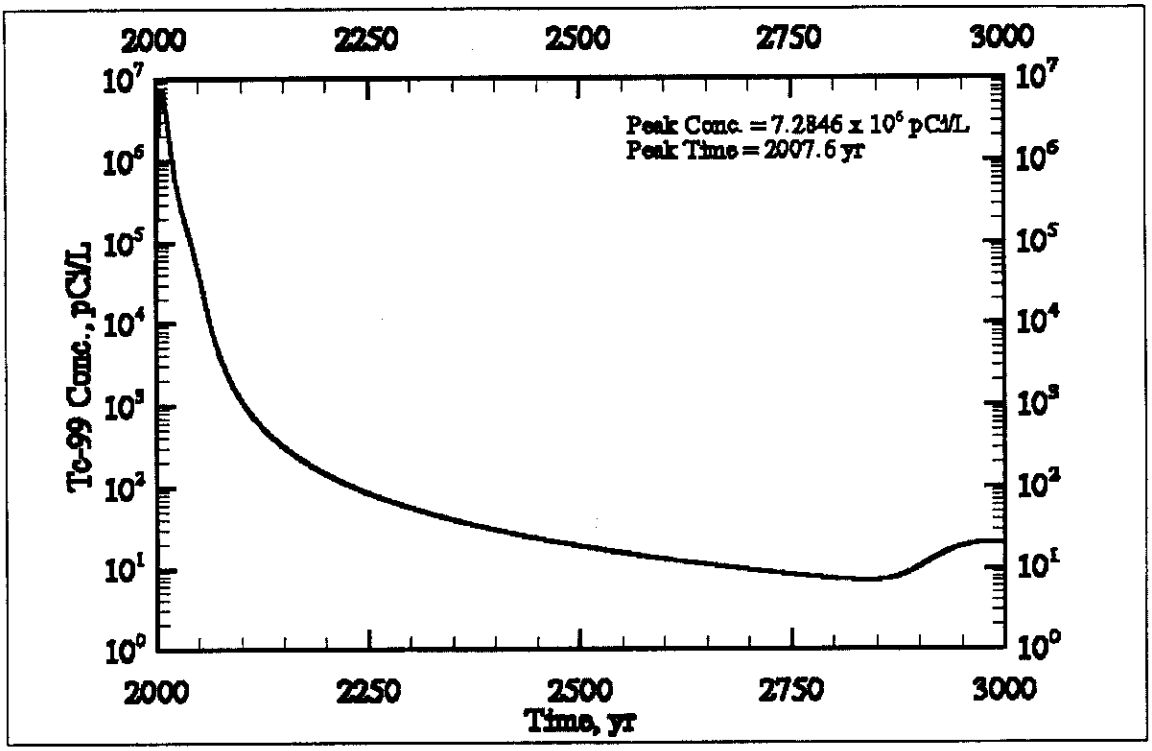


Figure E3.98. Case 7 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

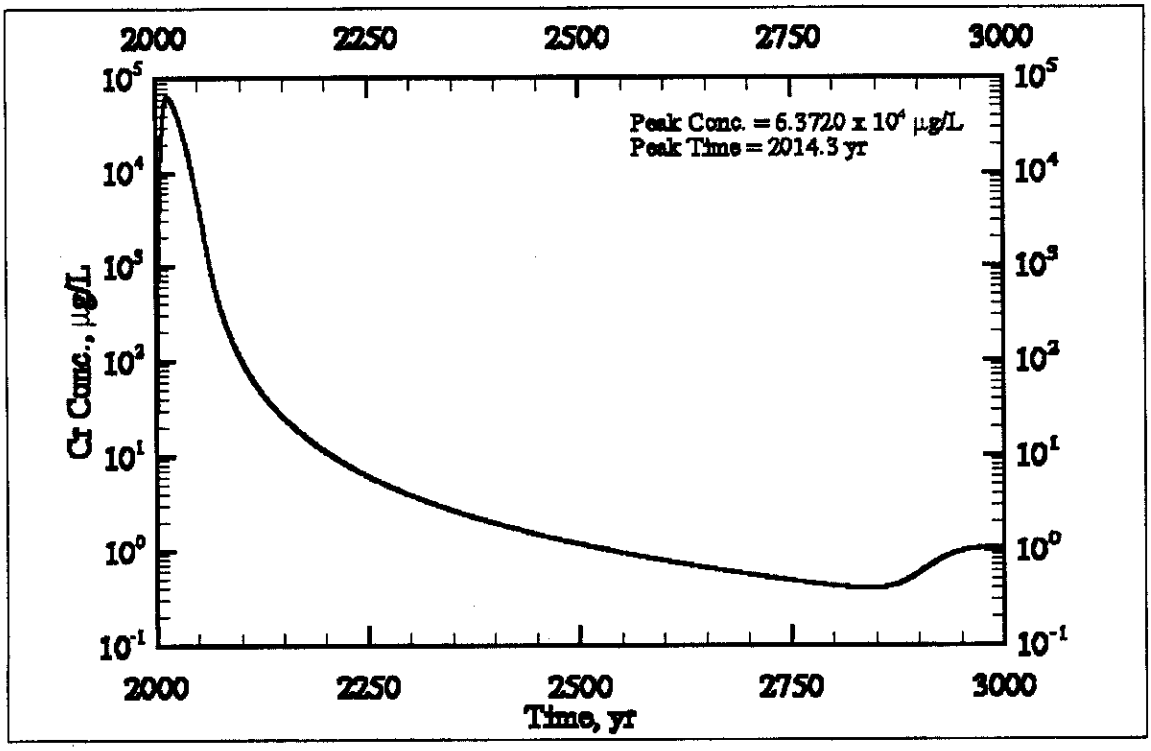


Figure E3.99. Case 7 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

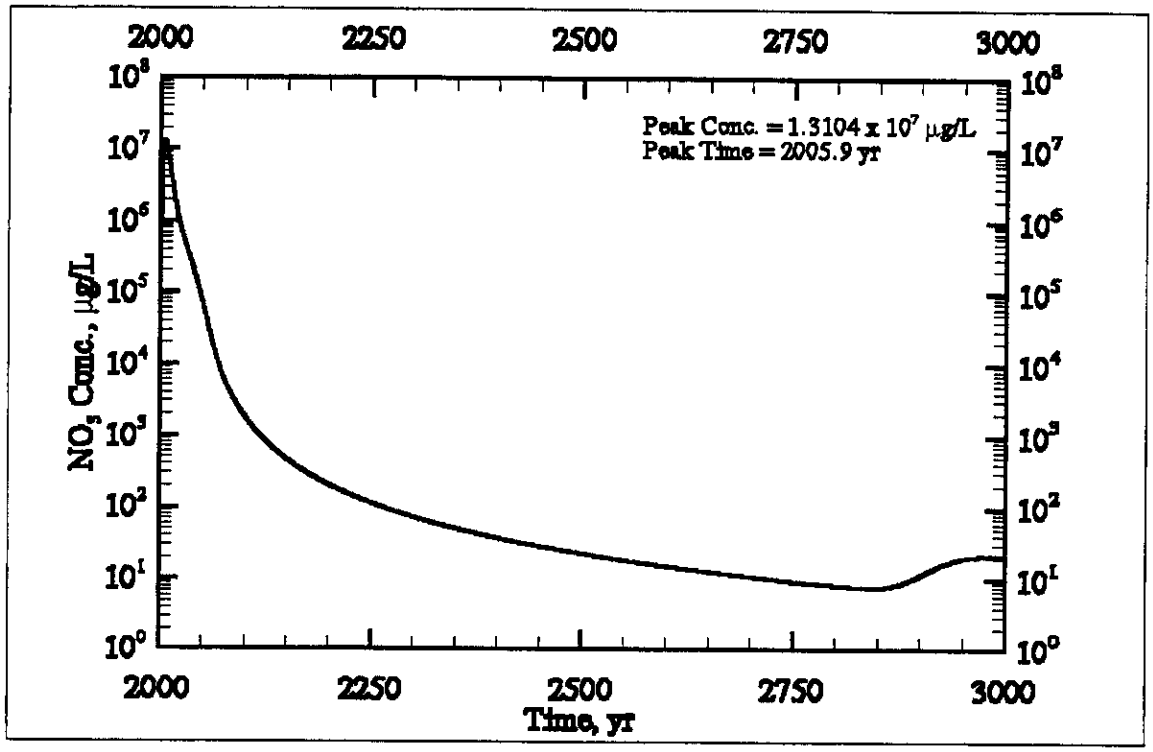


Figure E3.100. Case 7 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

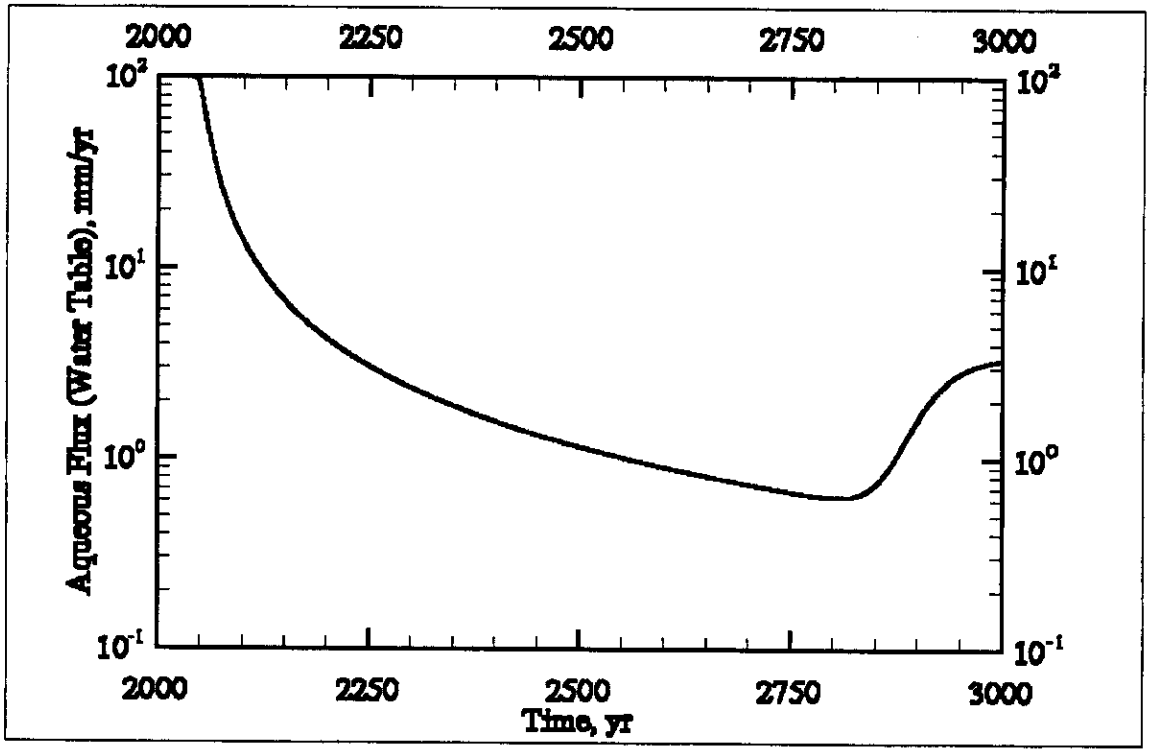


Figure E3.101. Case 7 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

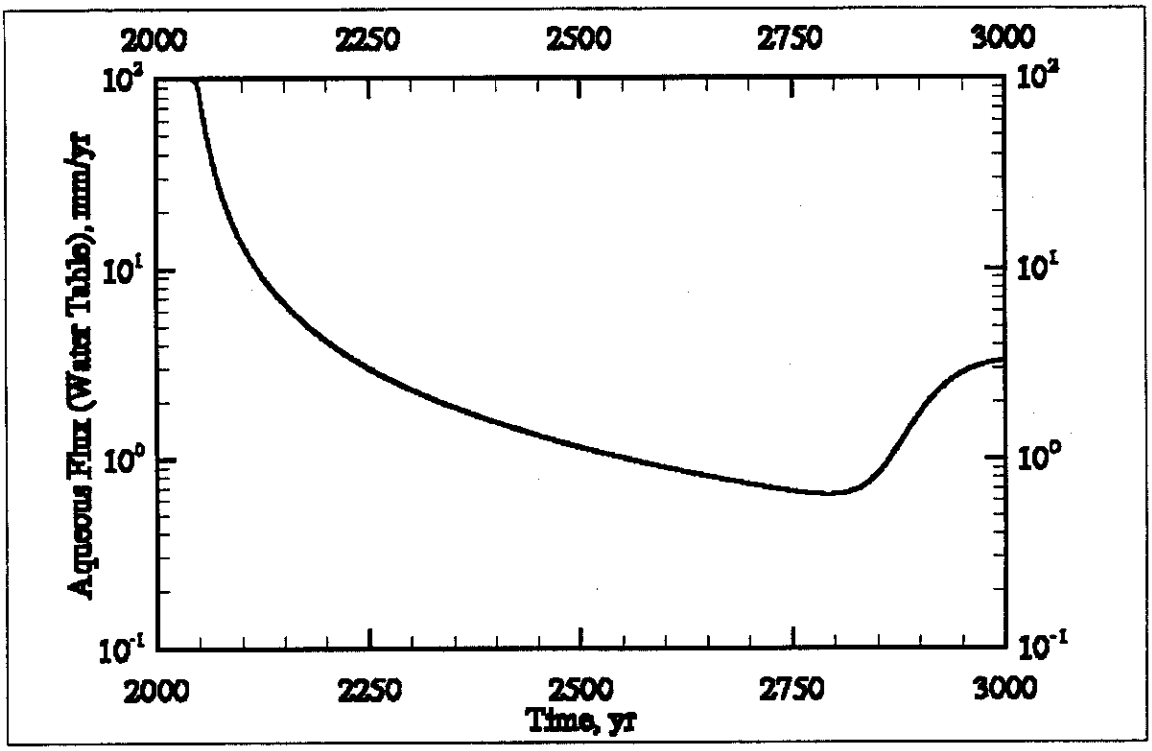


Figure E3.102. Case 7 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

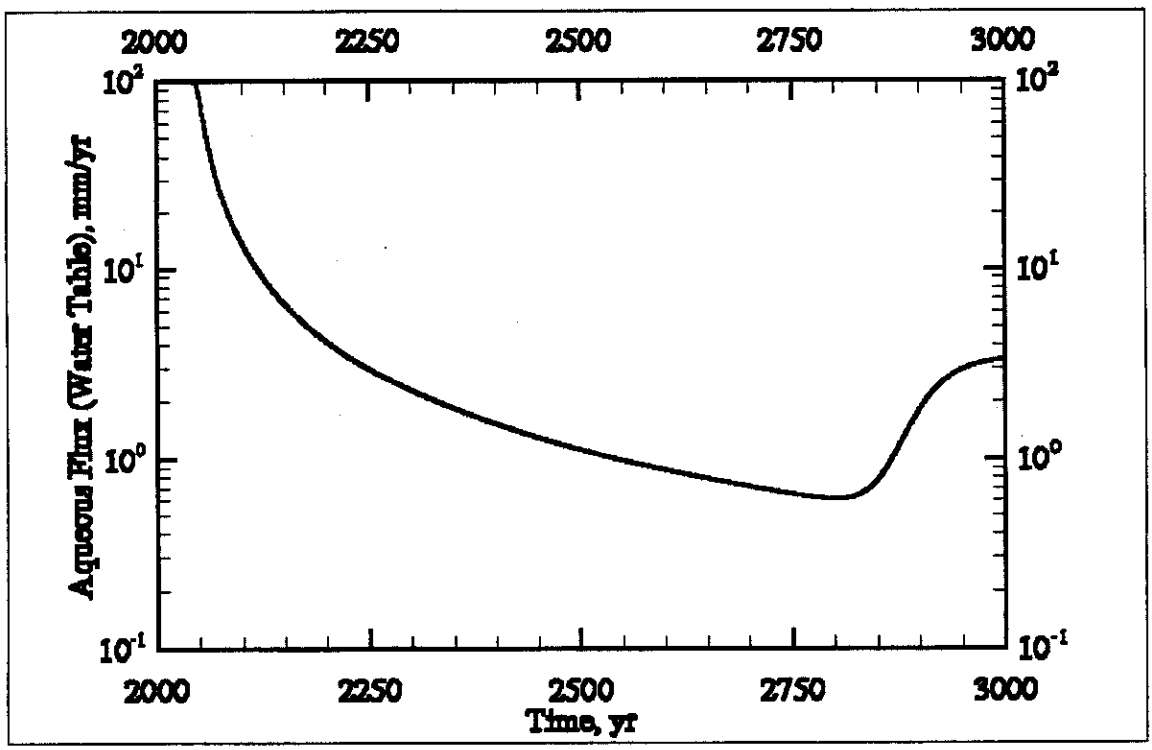


Figure E3.103. Case 7 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

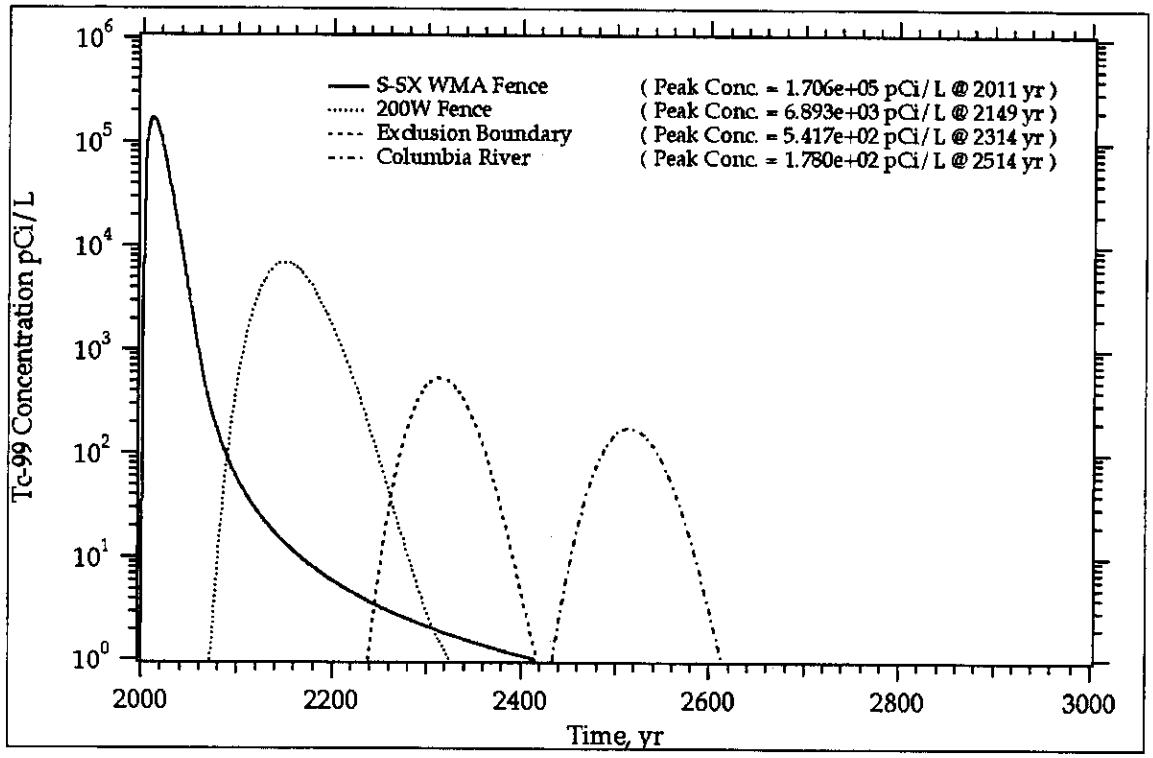


Figure E3.104. Case 7 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

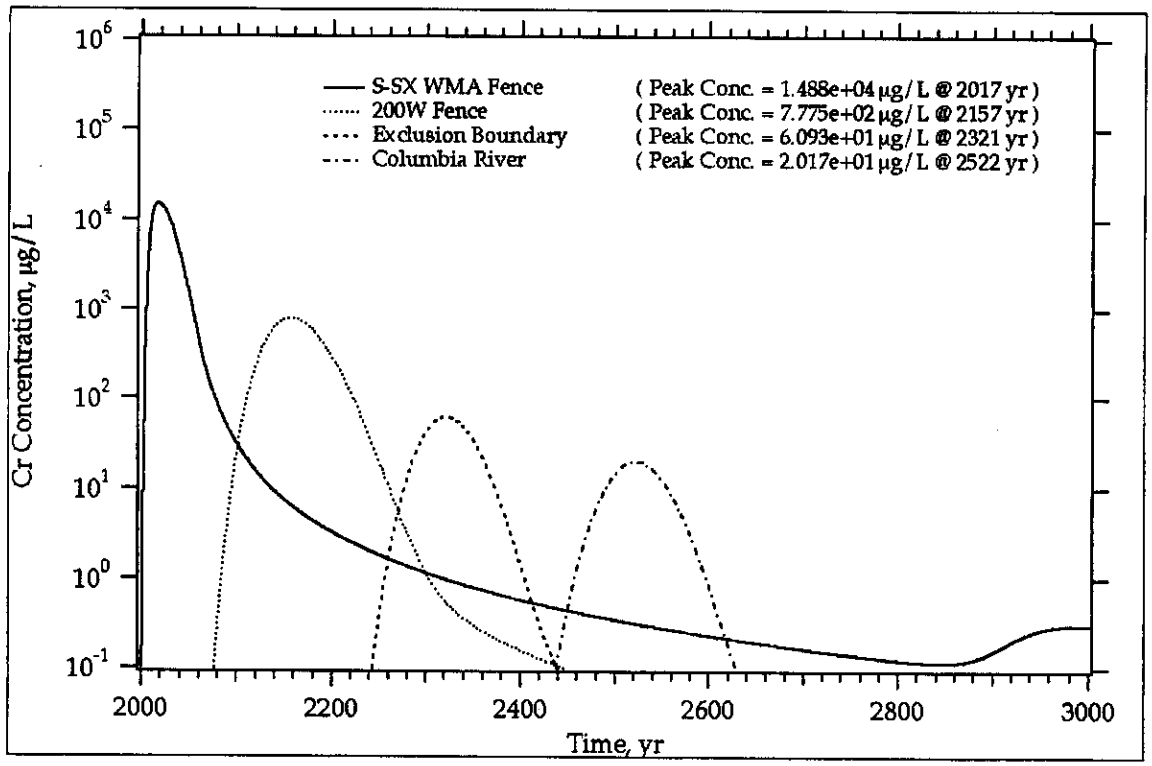
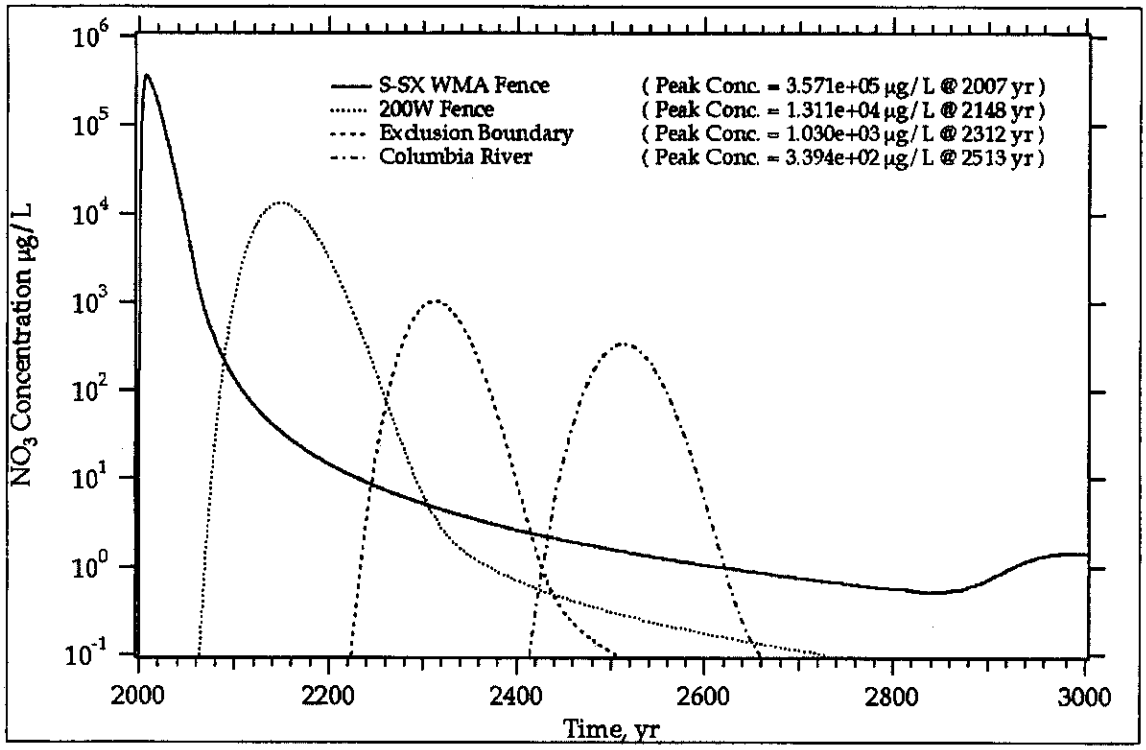


Figure E3.105. Case 7 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.8.0 CASE 8: DENSITY AND VISCOSITY EFFECTS

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only, no water-line leak, enhanced density and viscosity, no barrier until closure in 2040, and a uniform inventory distribution.

Figure E3.106. Case 8 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

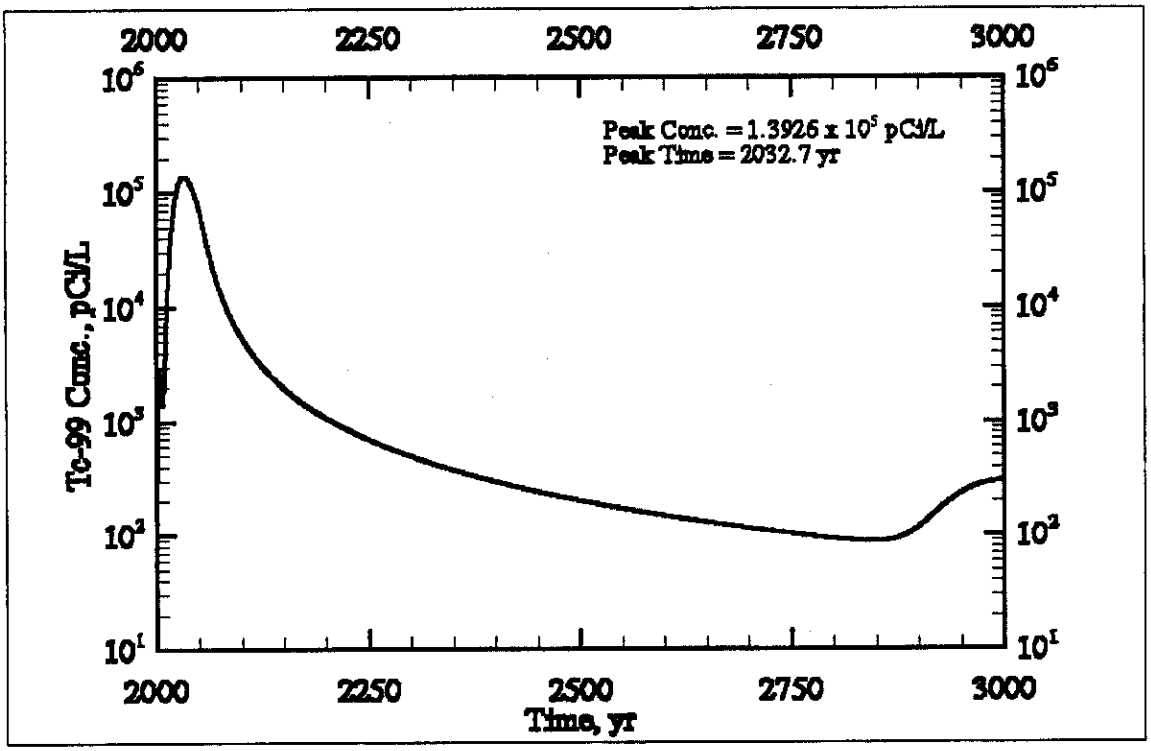


Figure E3.107. Case 8 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

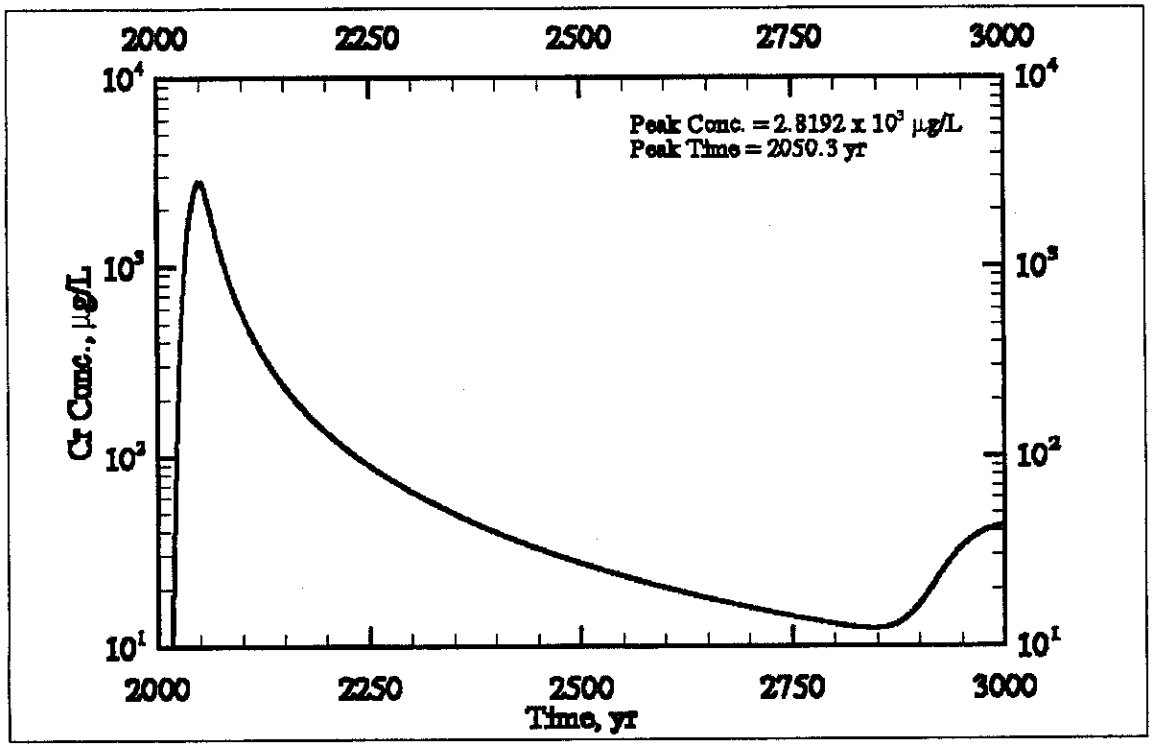


Figure E3.108. Case 8 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

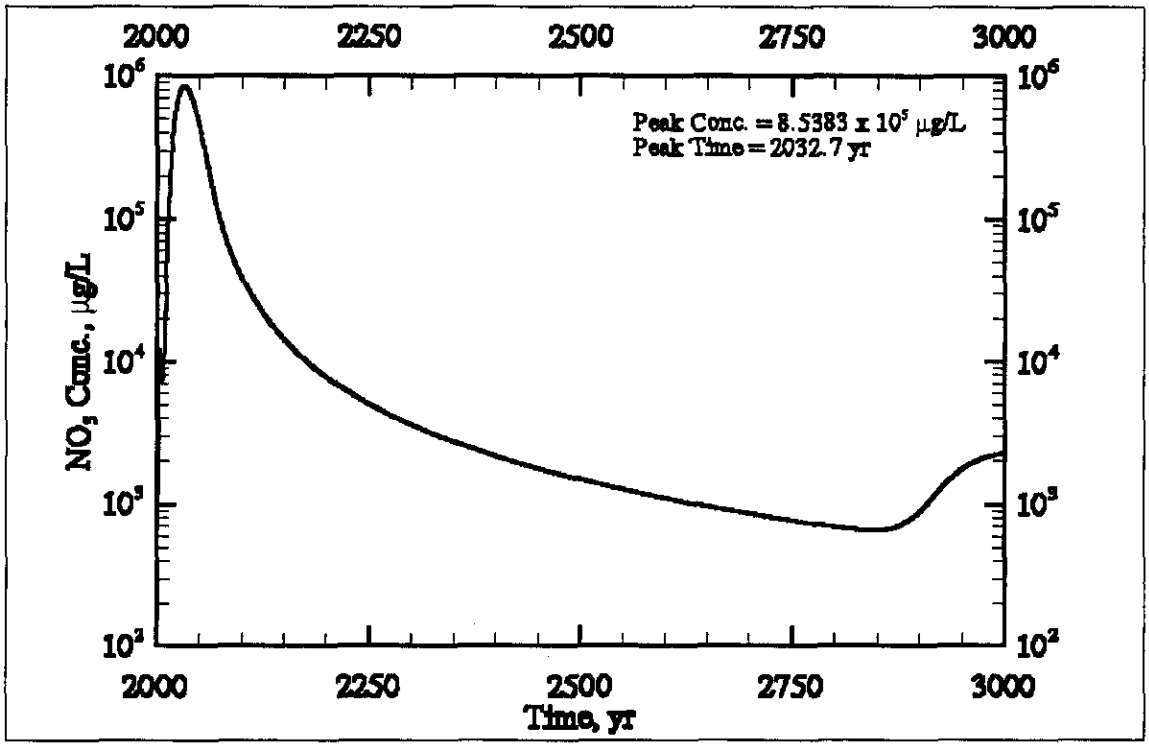


Figure E3.109. Case 8 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

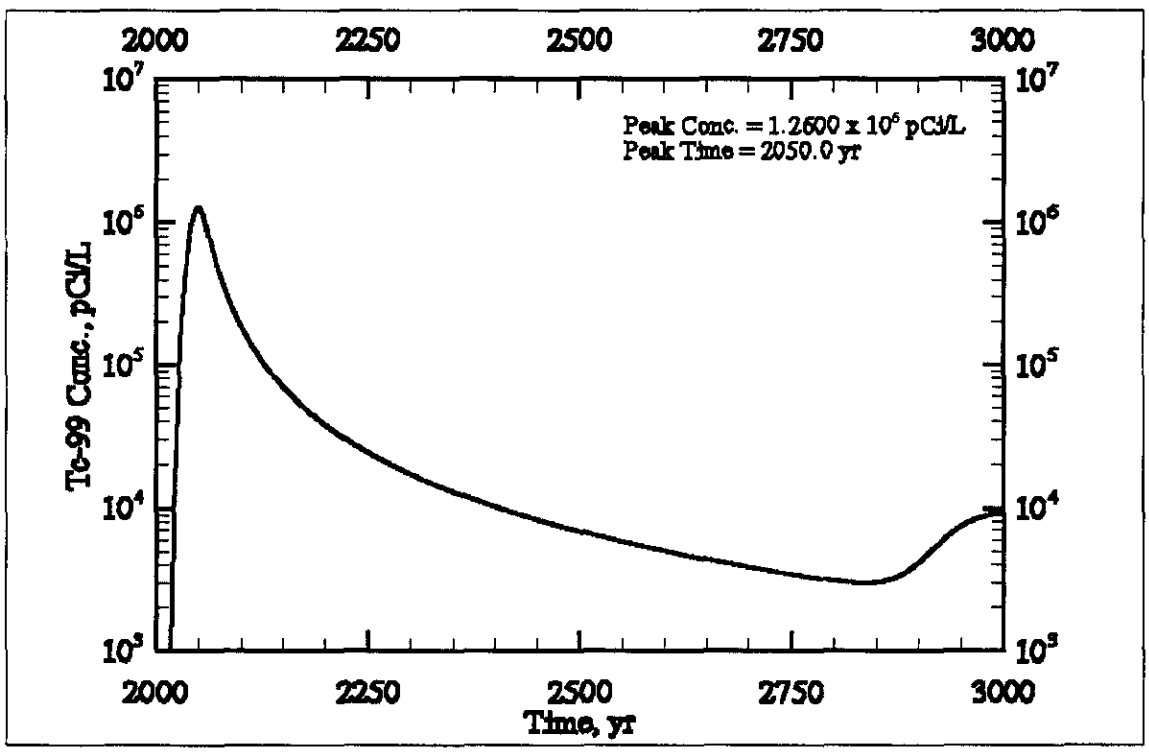


Figure E3.110. Case 8 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

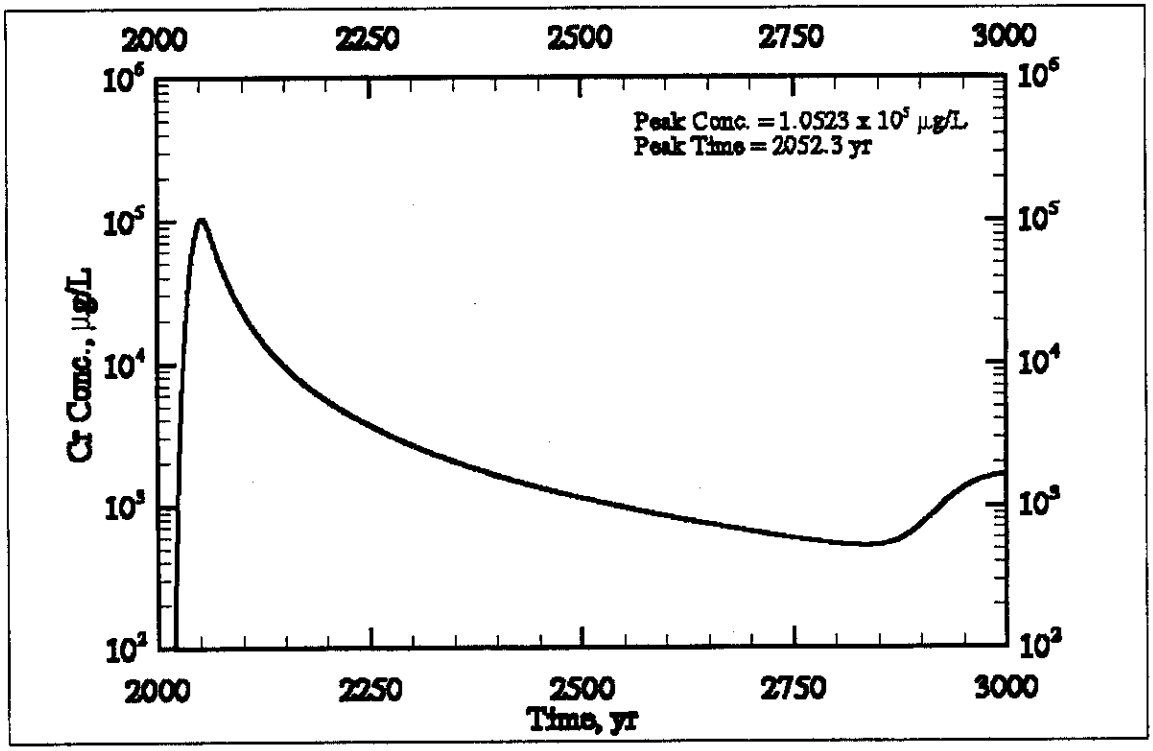


Figure E3.111. Case 8 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

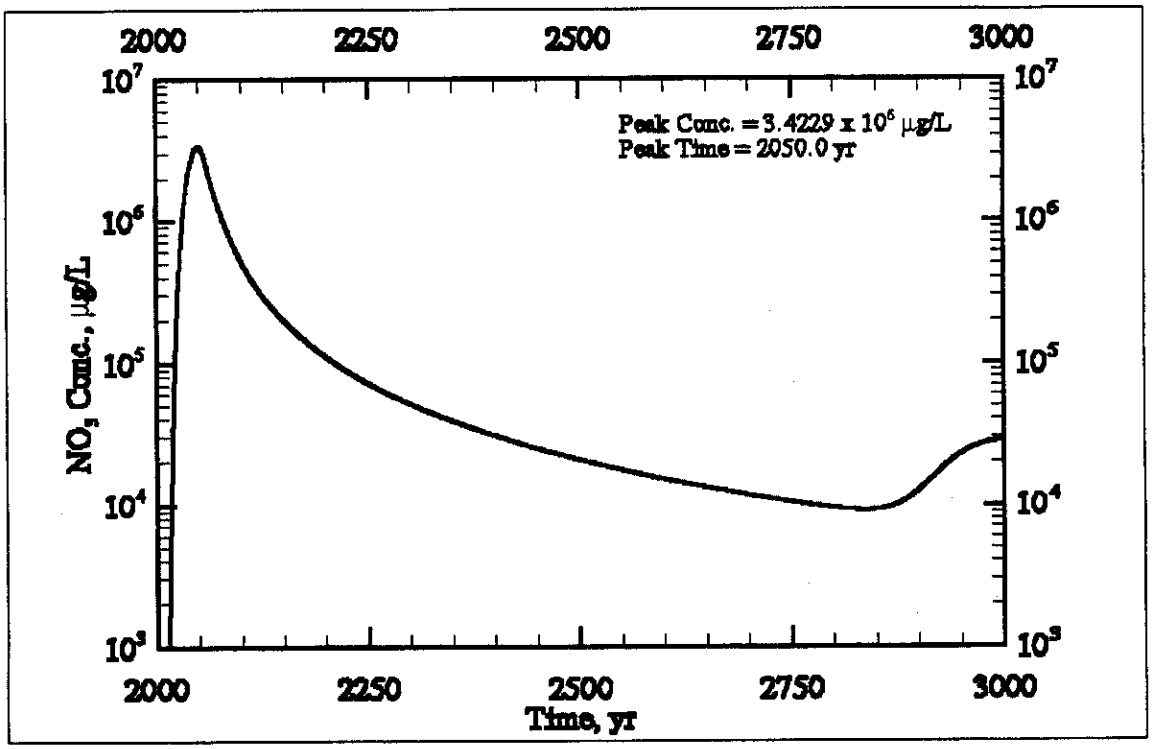


Figure E3.112. Case 8 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

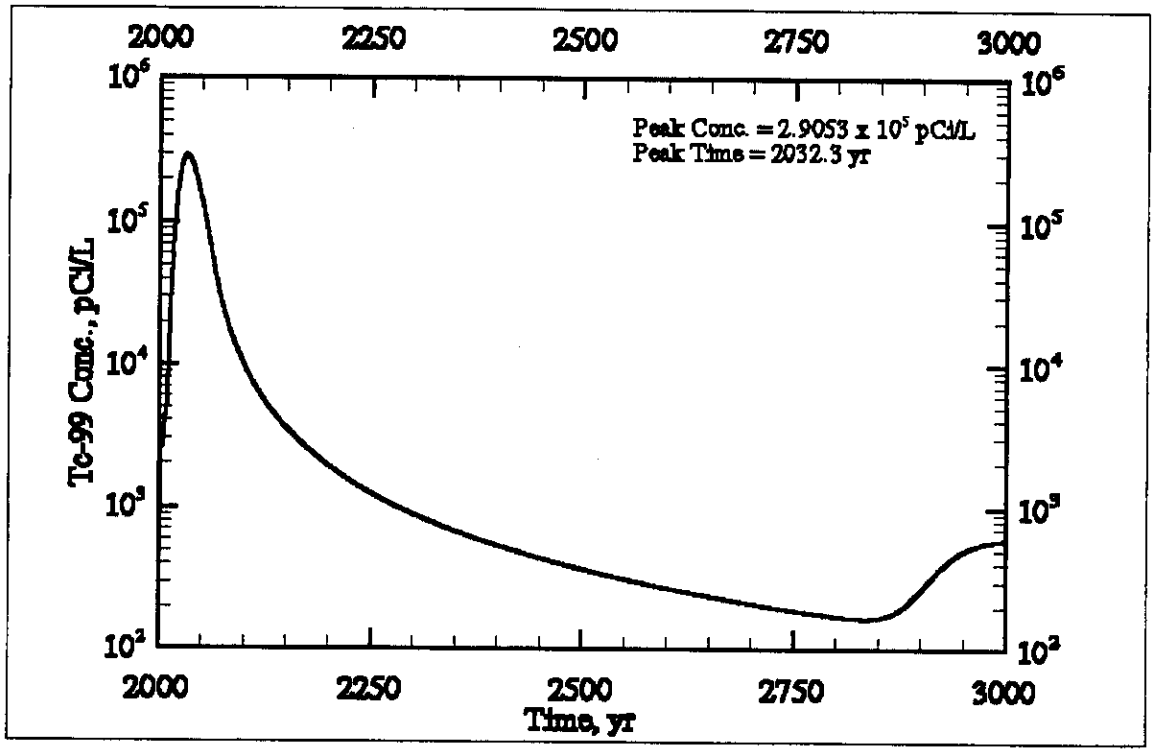


Figure E3.113. Case 8 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

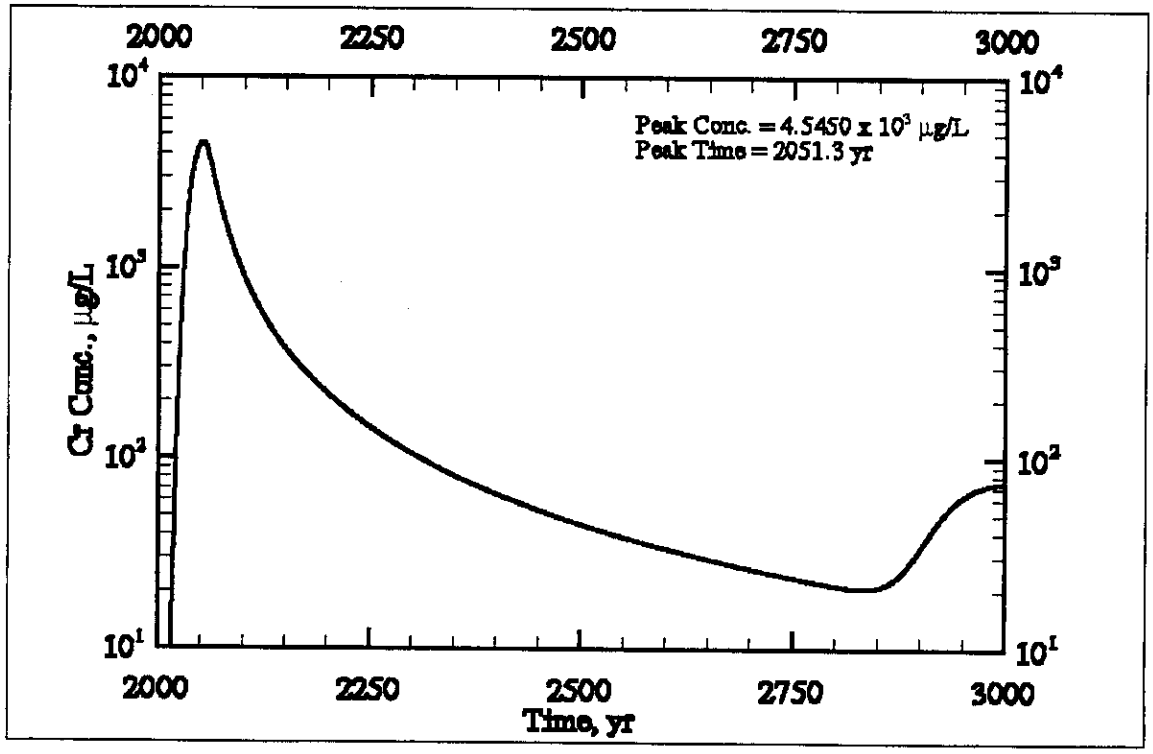


Figure E3.114. Case 8 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

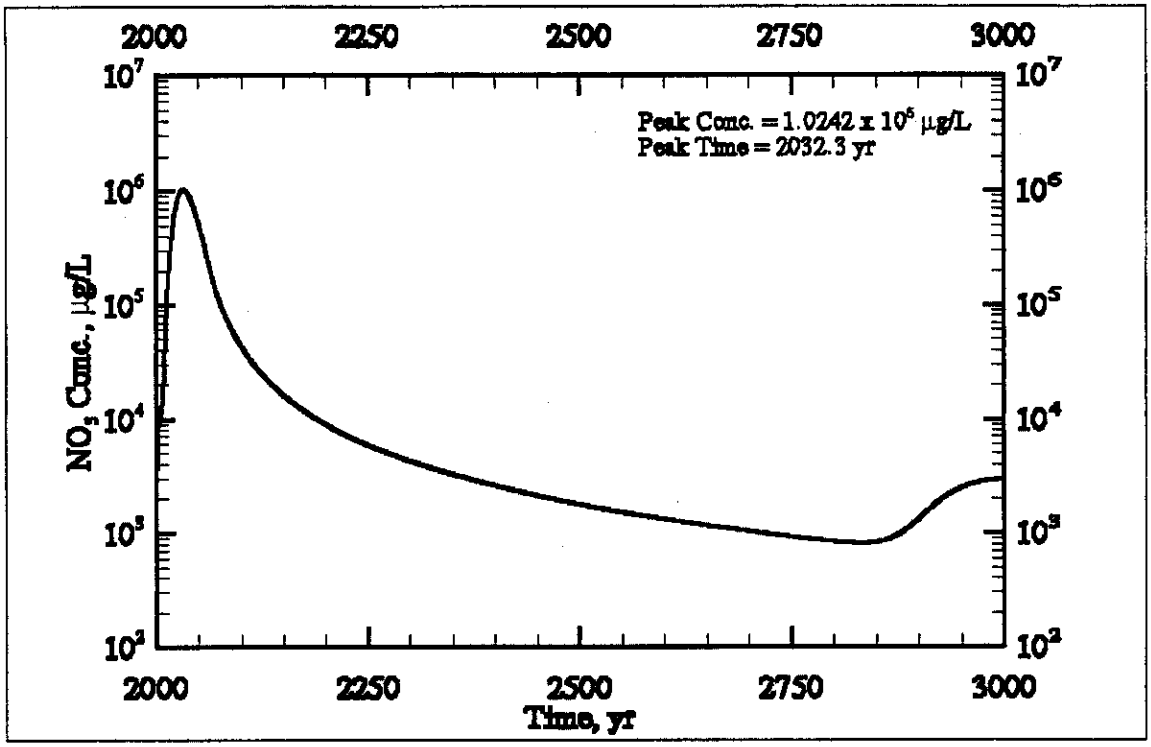


Figure E3.115. Case 8 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

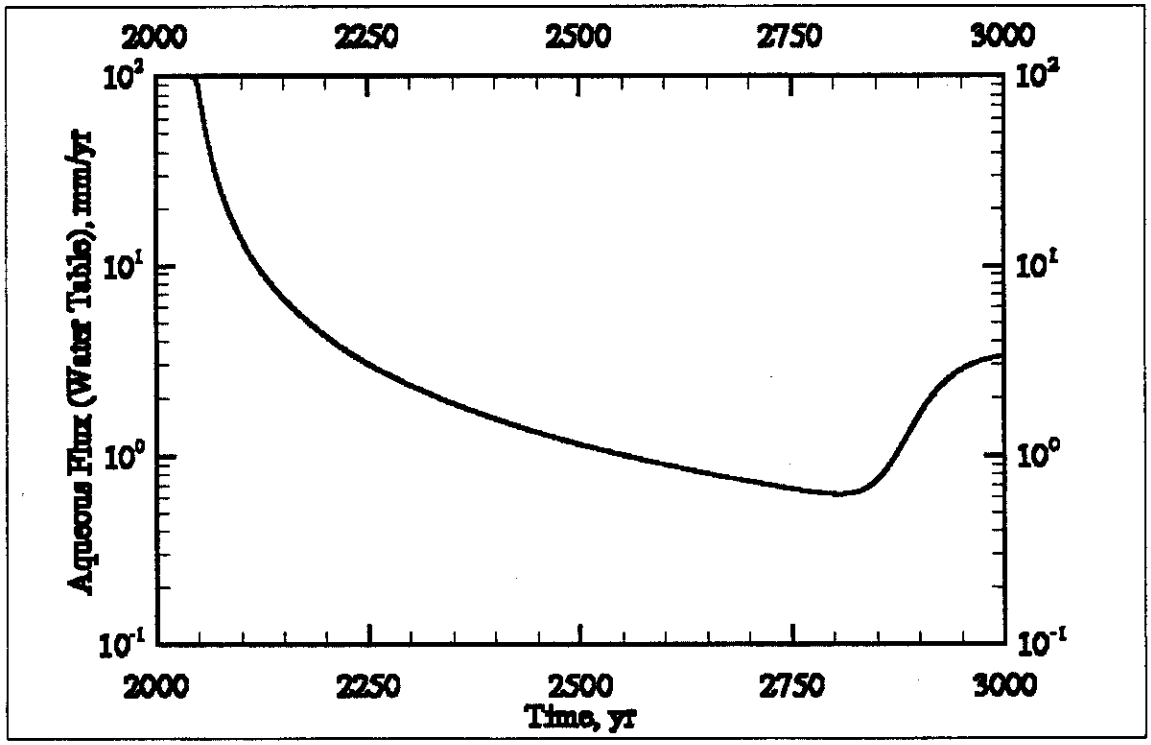


Figure E3.116. Case 8 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

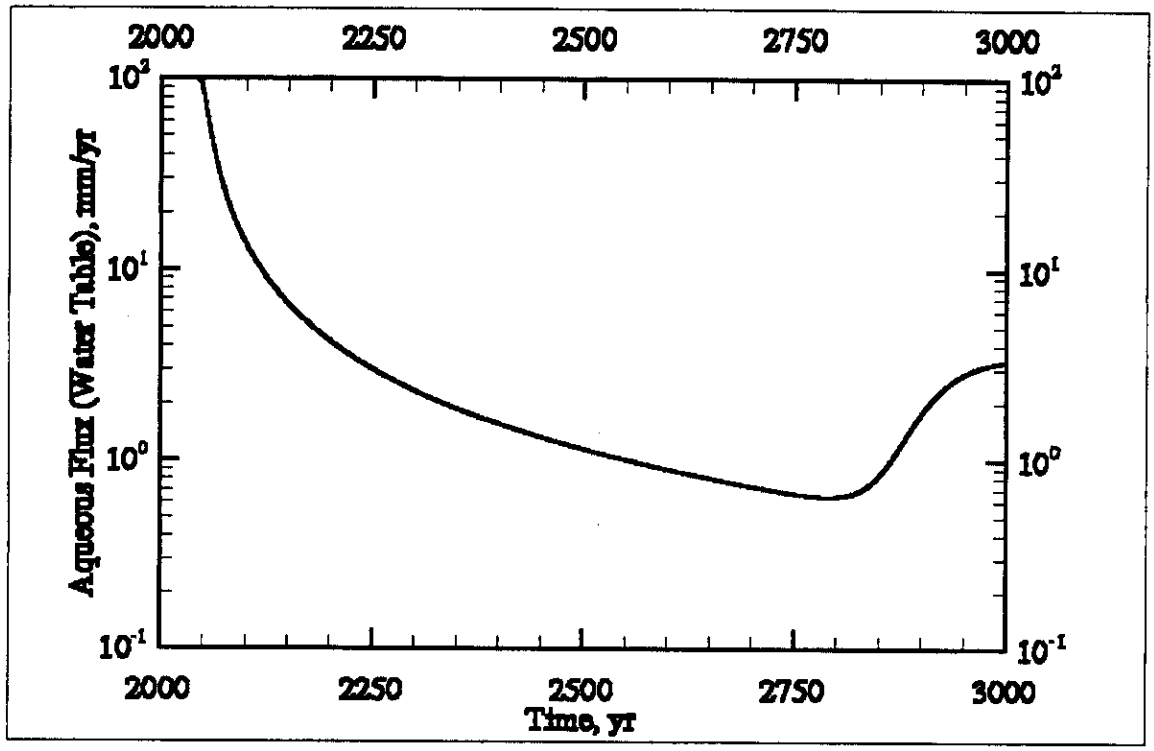


Figure E3.117. Case 8 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

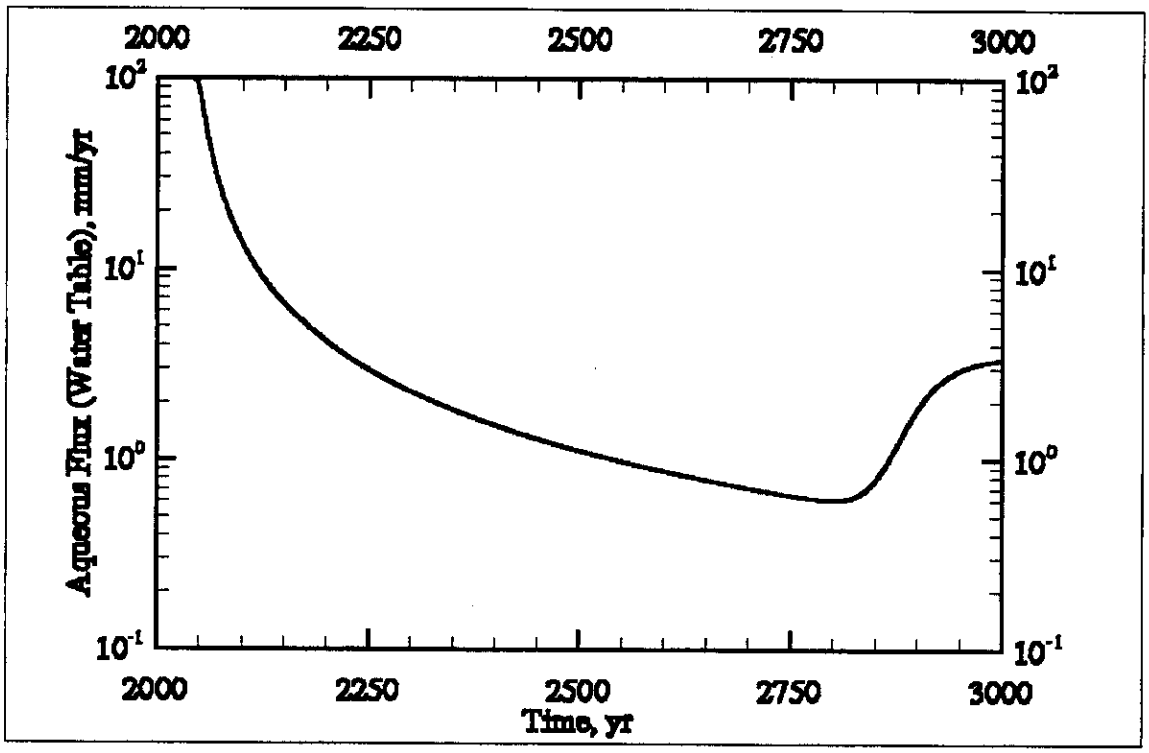


Figure E3.118. Case 8 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

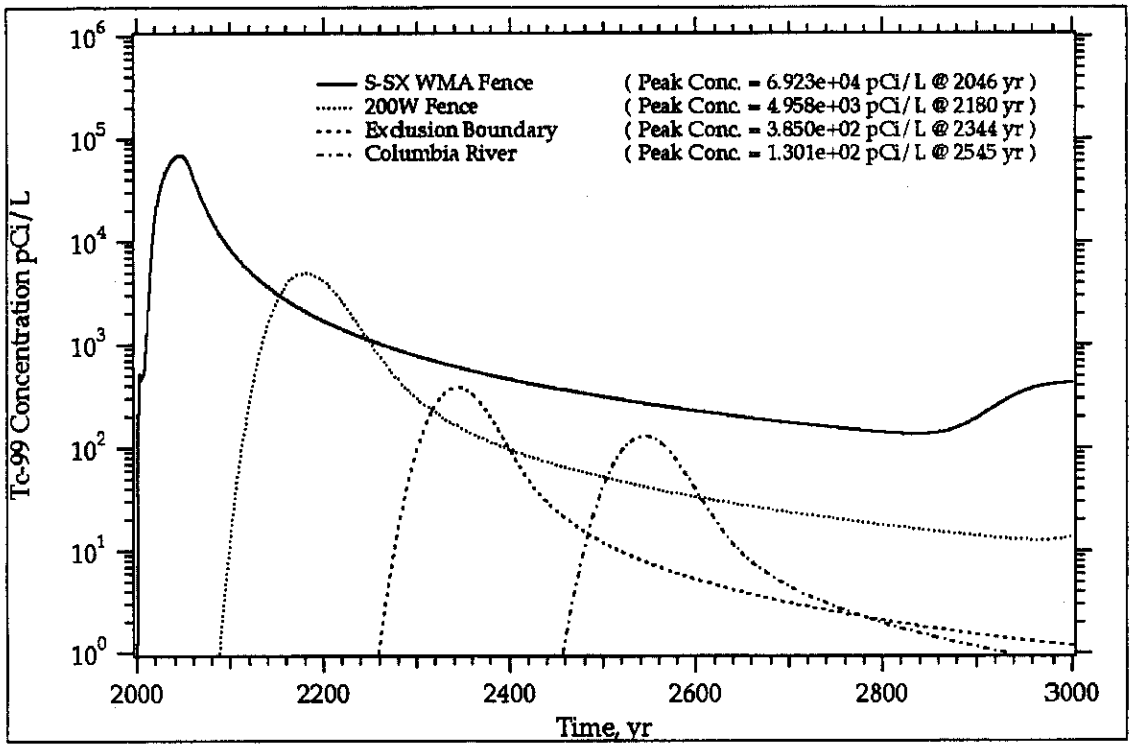


Figure E3.119. Case 8 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

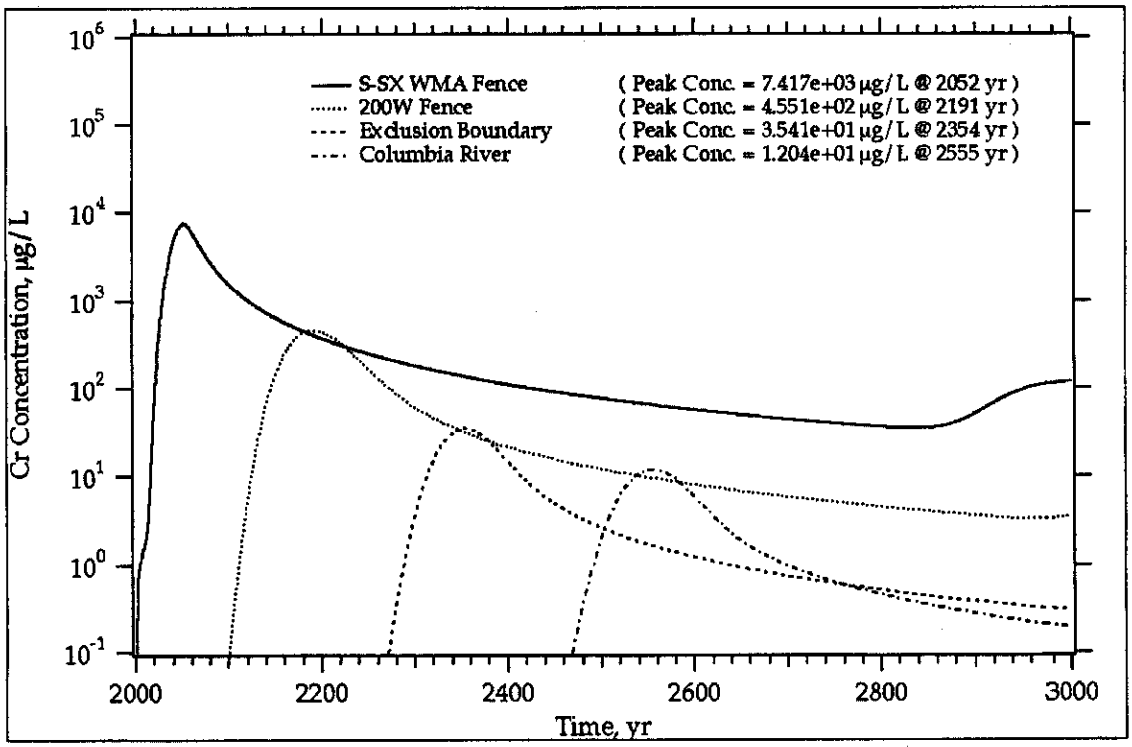
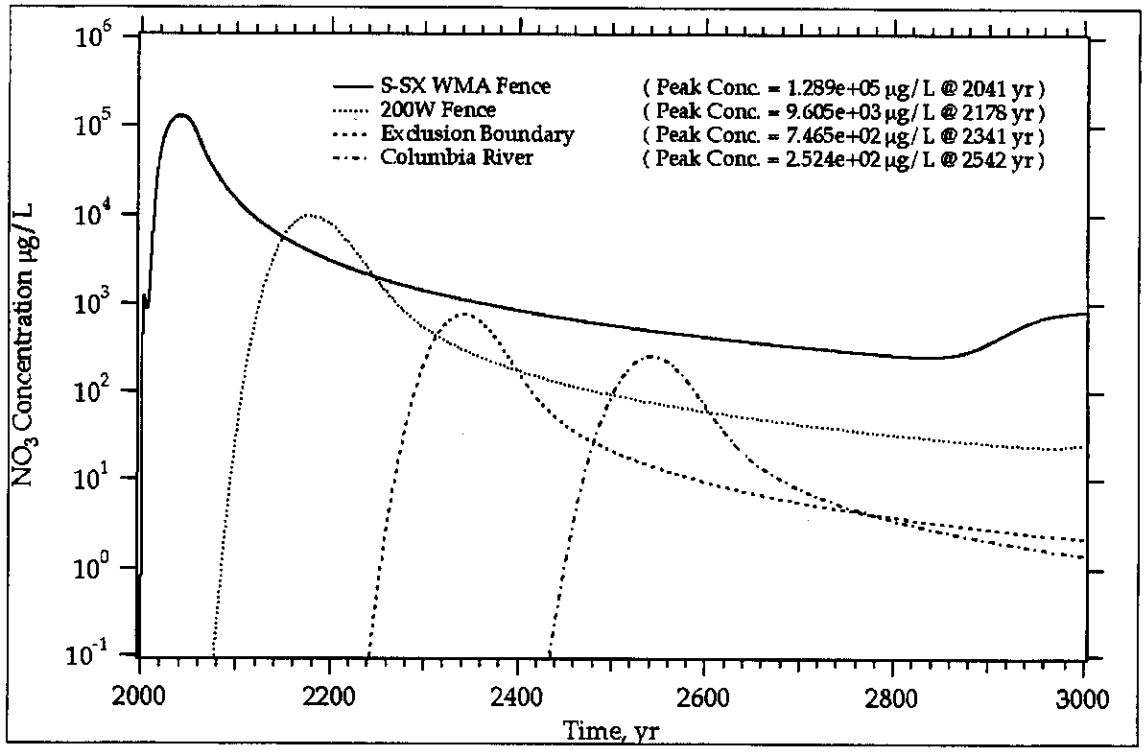


Figure E3.120. Case 8 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.9.0 CASE 9: BASE CASE (50 MM/YR METEORIC RECHARGE)

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only at 50 mm/yr, no water-line leak, no interim barrier, a closure barrier by the year 2040, and a uniform inventory distribution.

Figure E3.121. Case 9 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

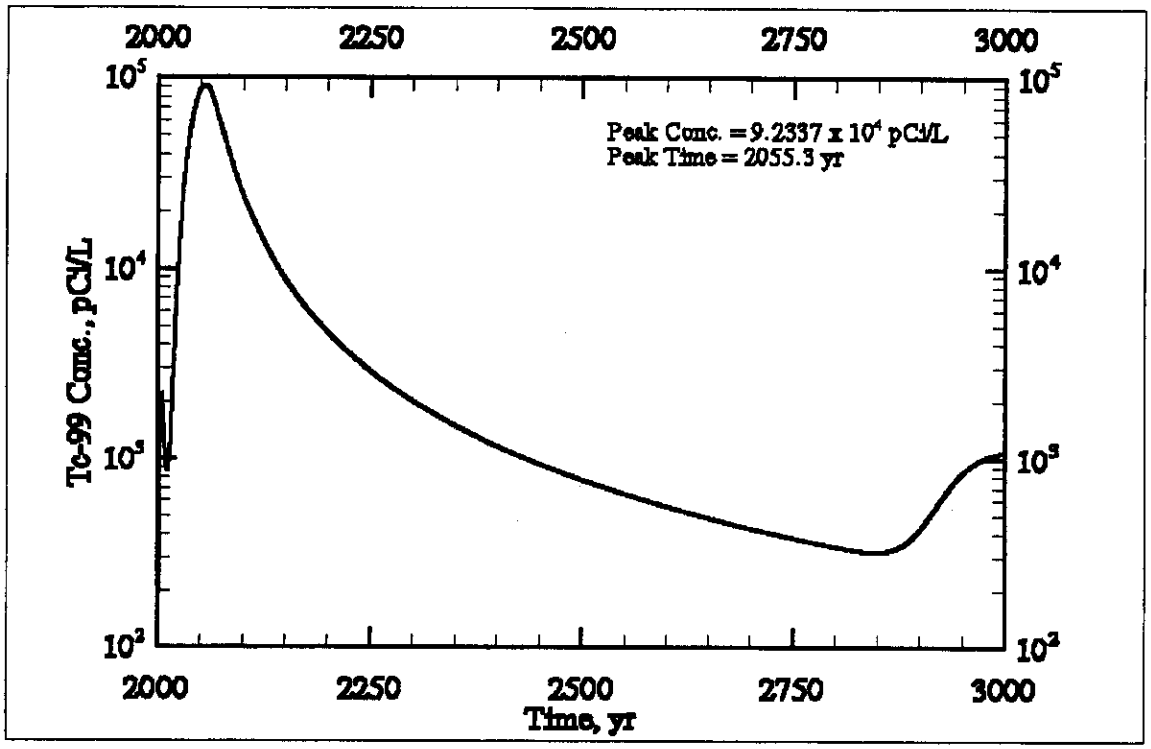


Figure E3.122. Case 9 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

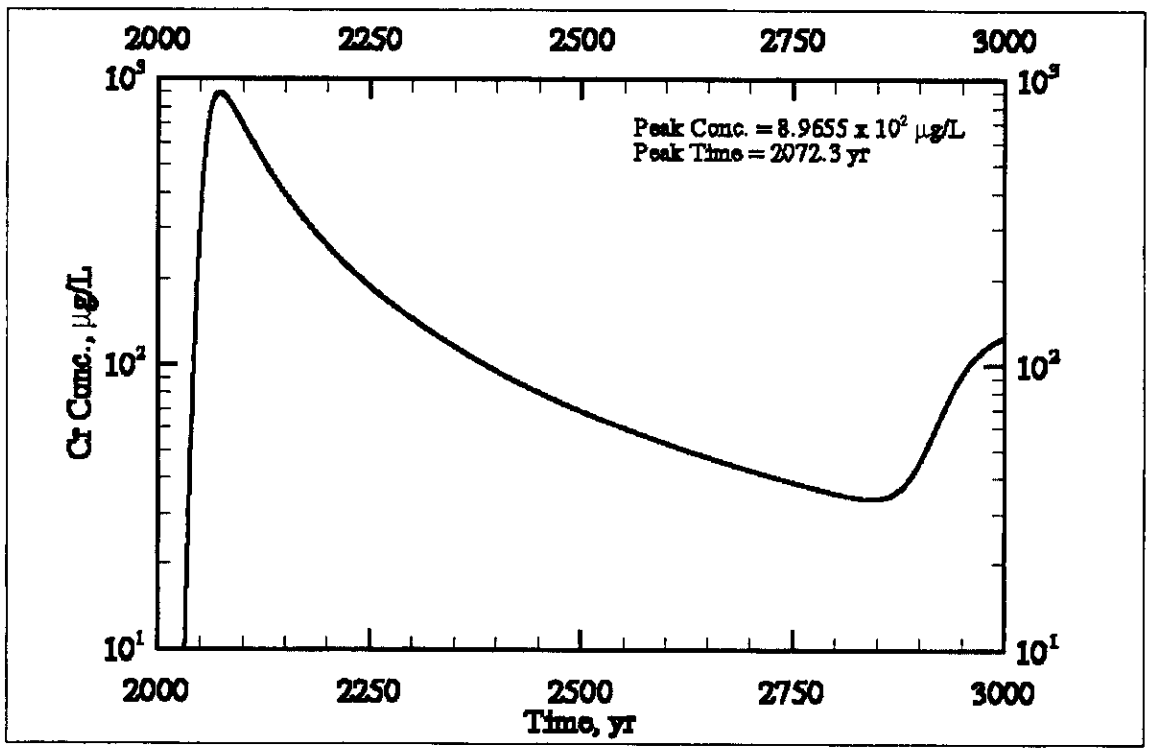


Figure E3.123. Case 9 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

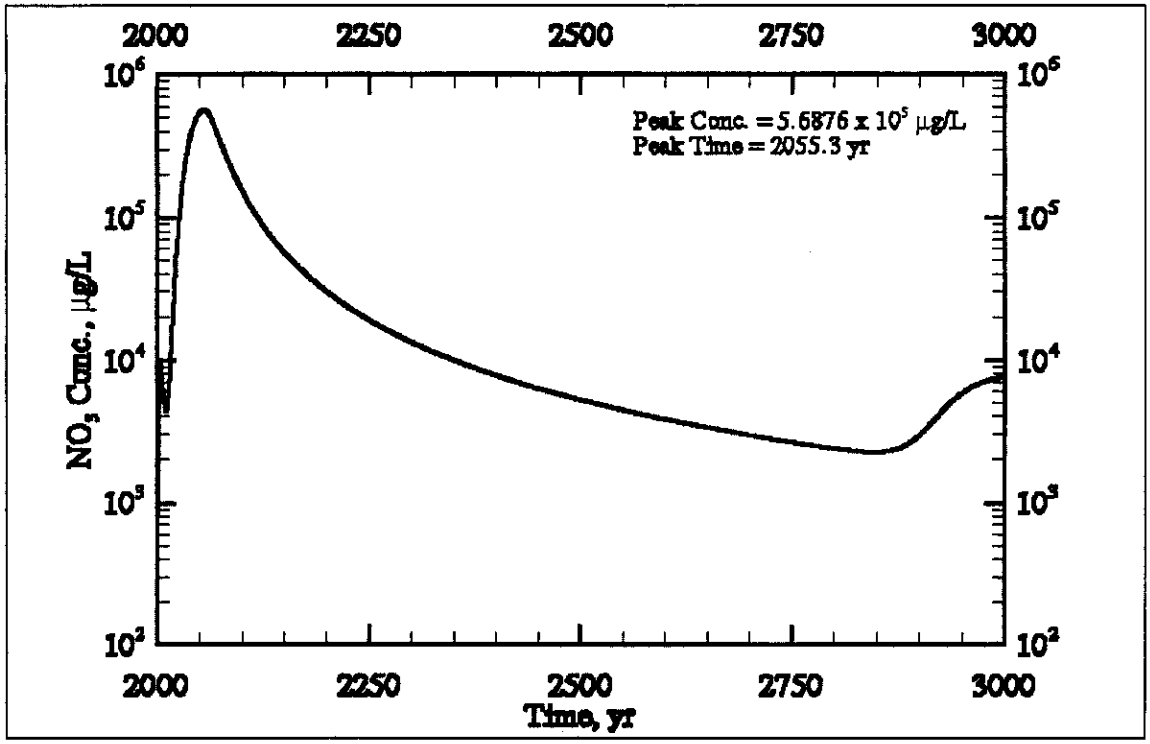


Figure E3.124. Case 9 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

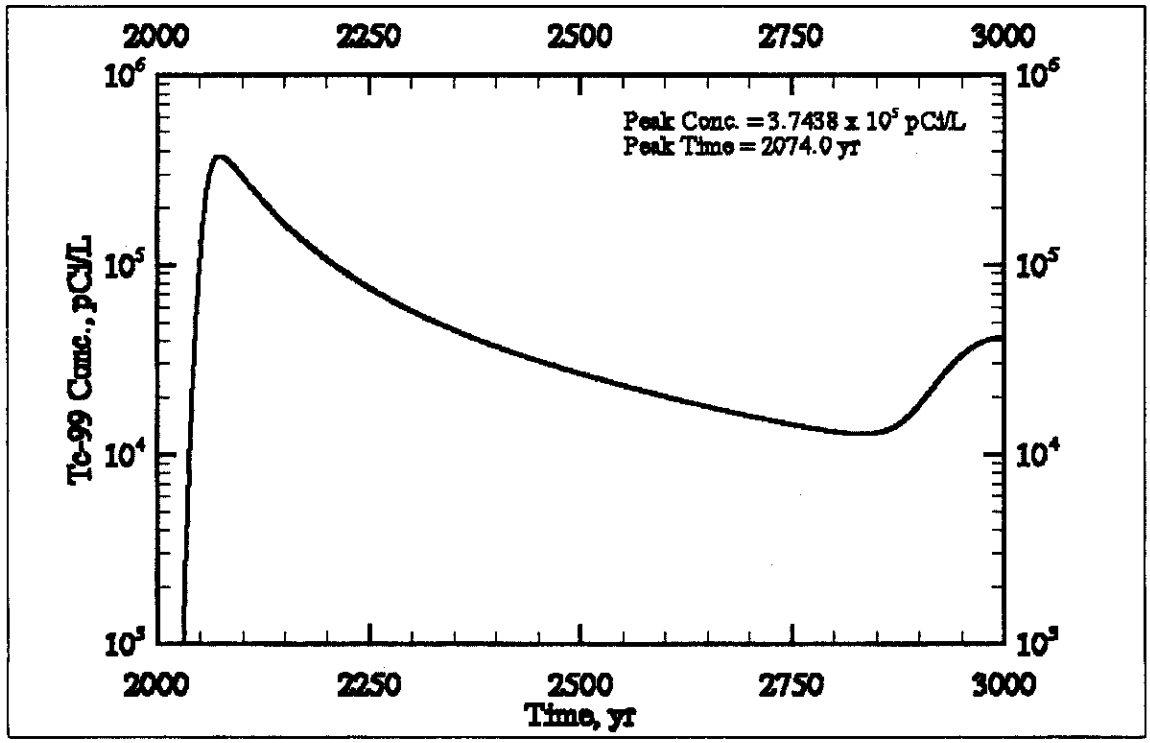


Figure E3.125. Case 9 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

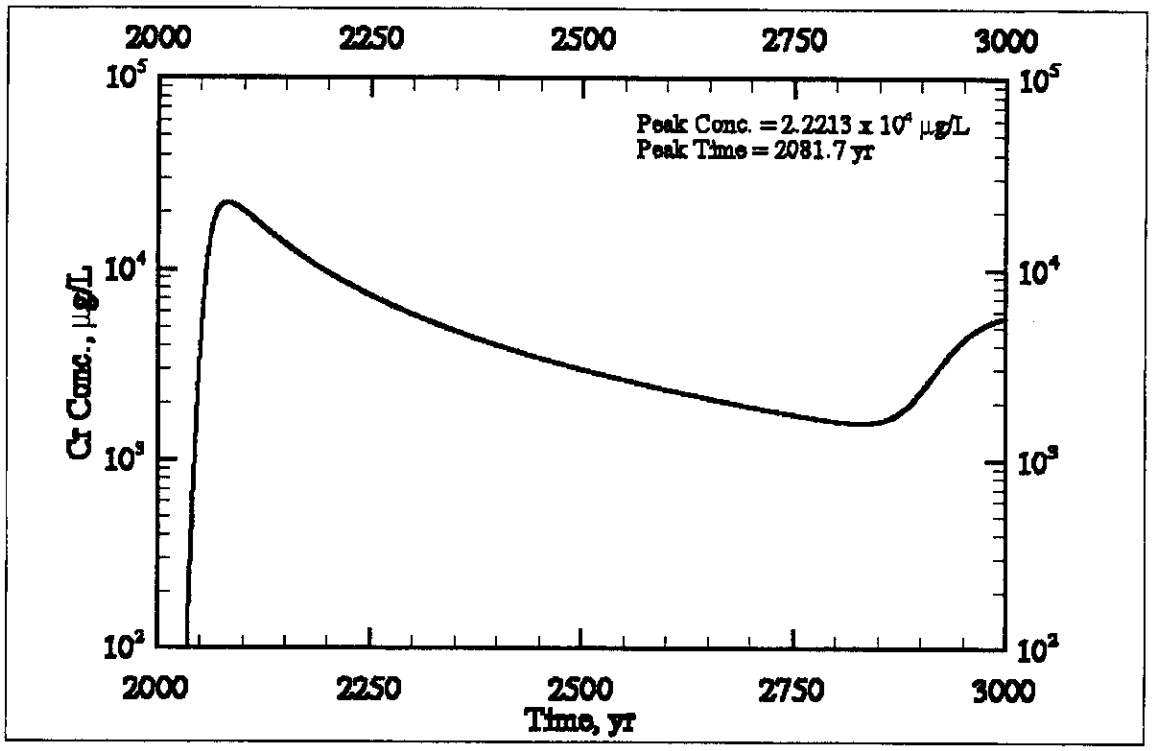


Figure E3.126. Case 9 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

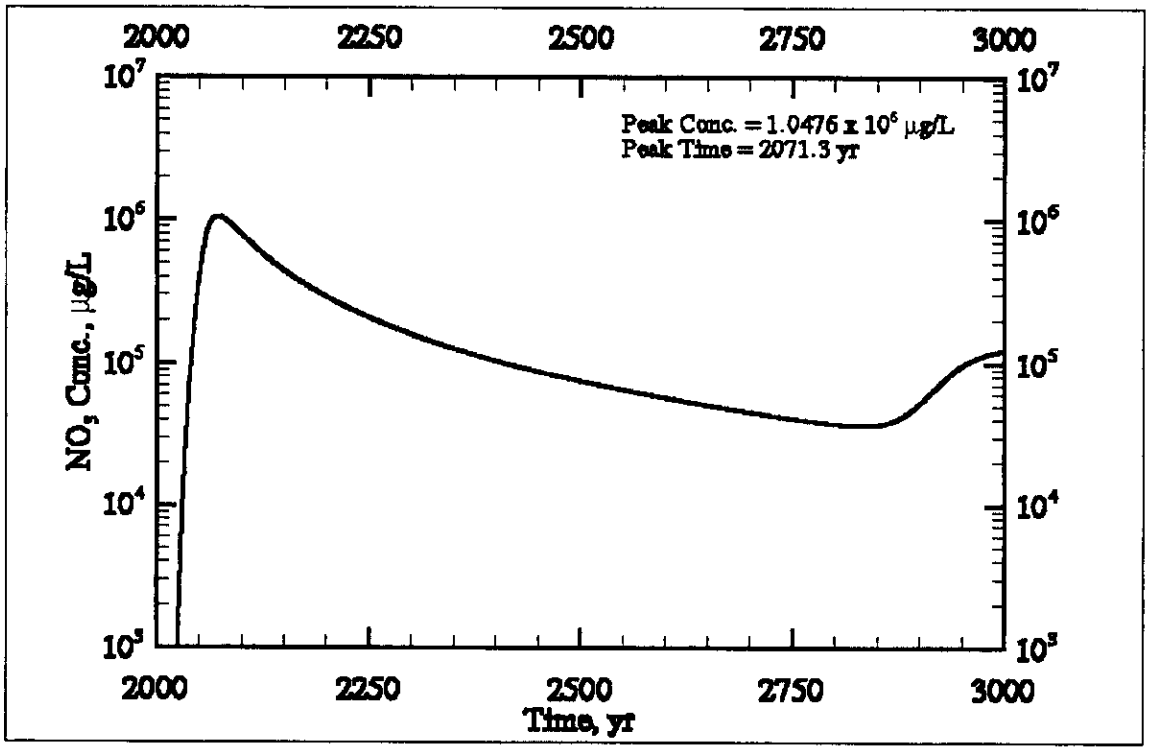


Figure E3.127. Case 9 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

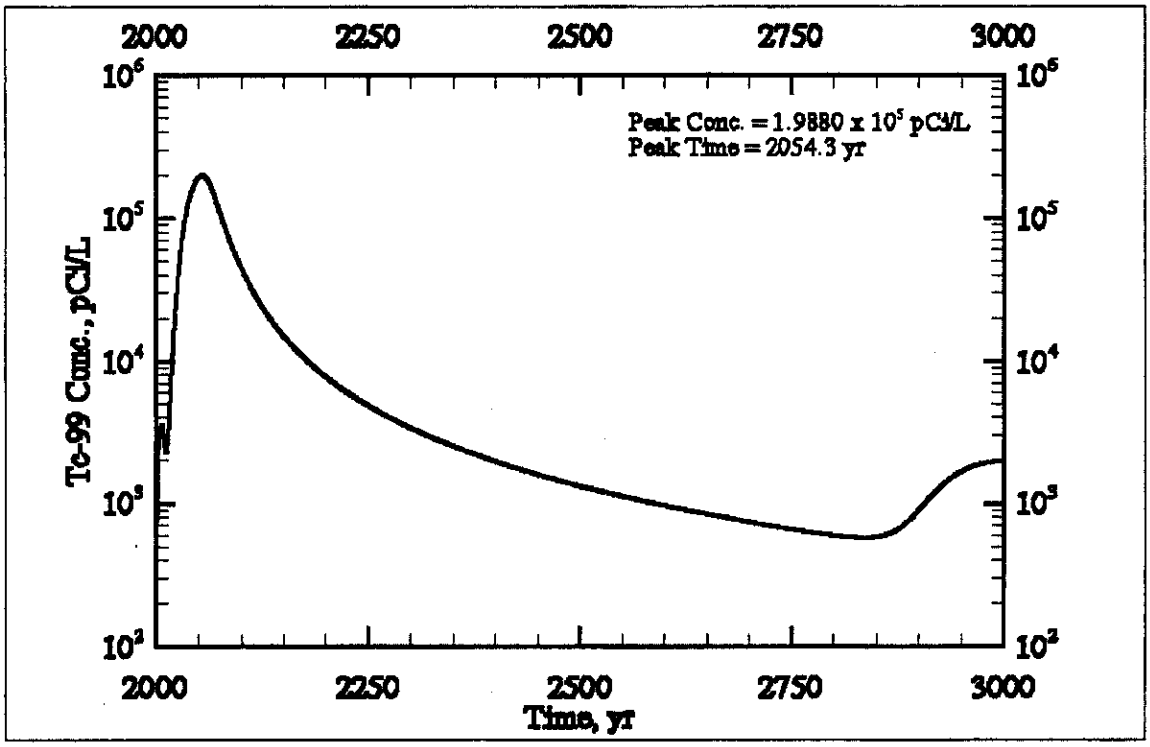


Figure E3.128. Case 9 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

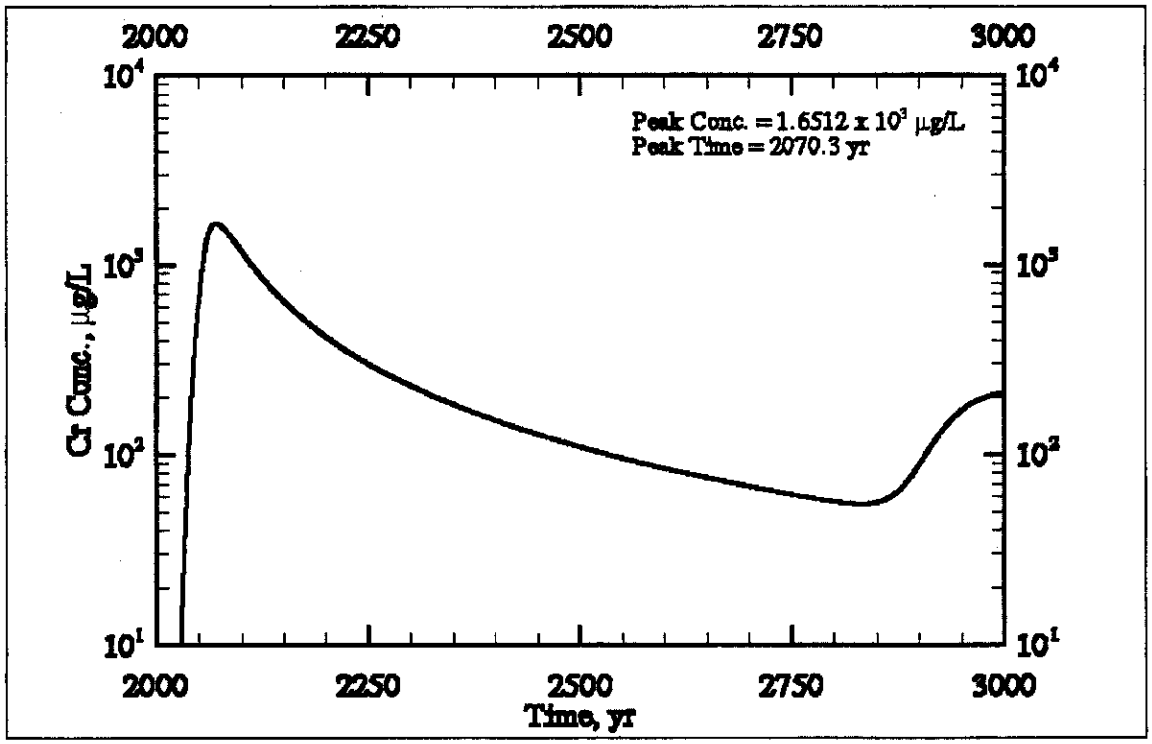


Figure E3.129. Case 9 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

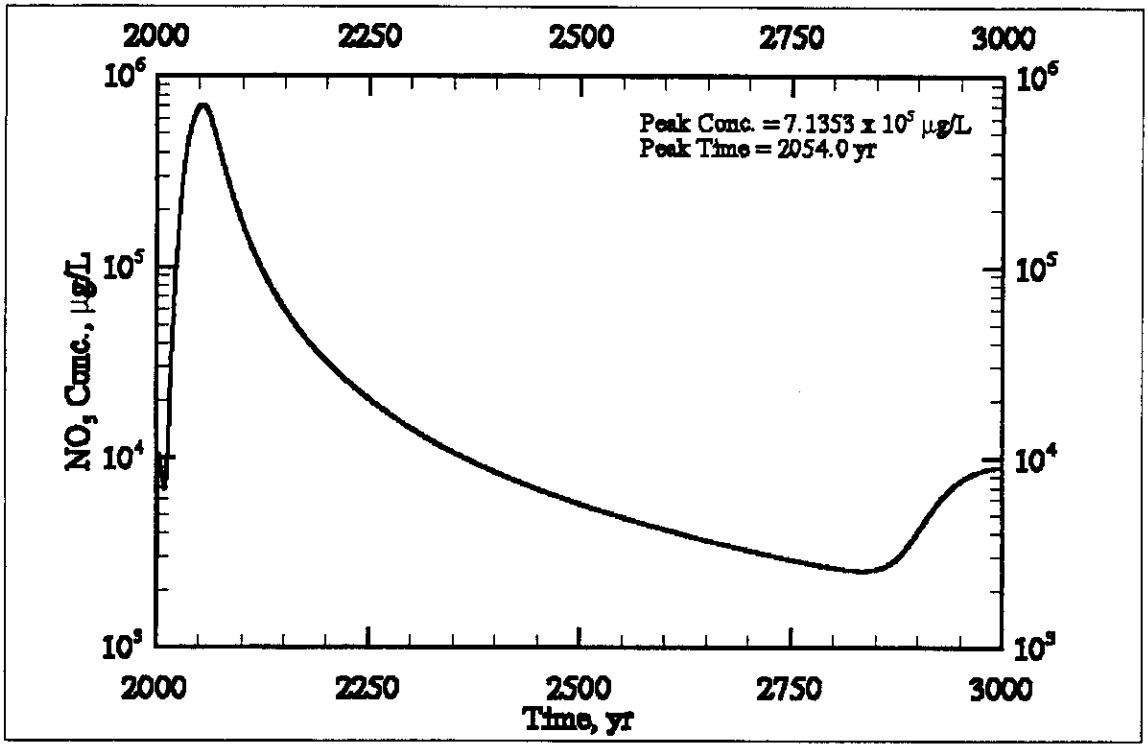


Figure E3.130. Case 9 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

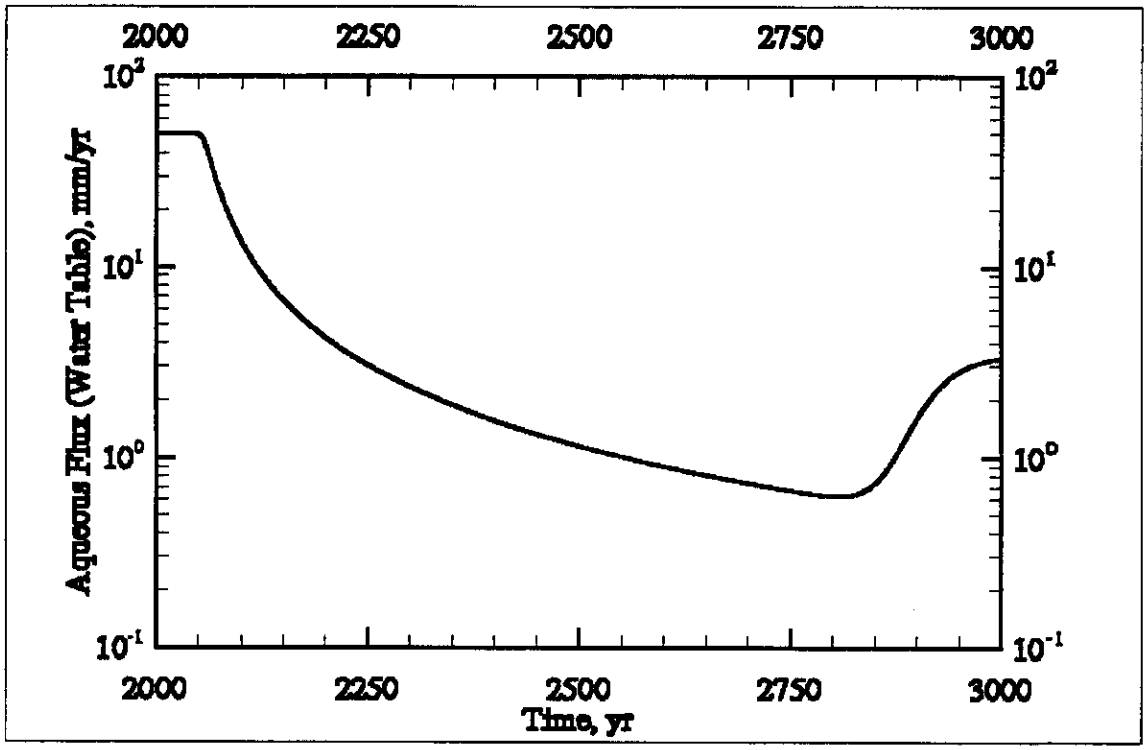


Figure E3.131. Case 9 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

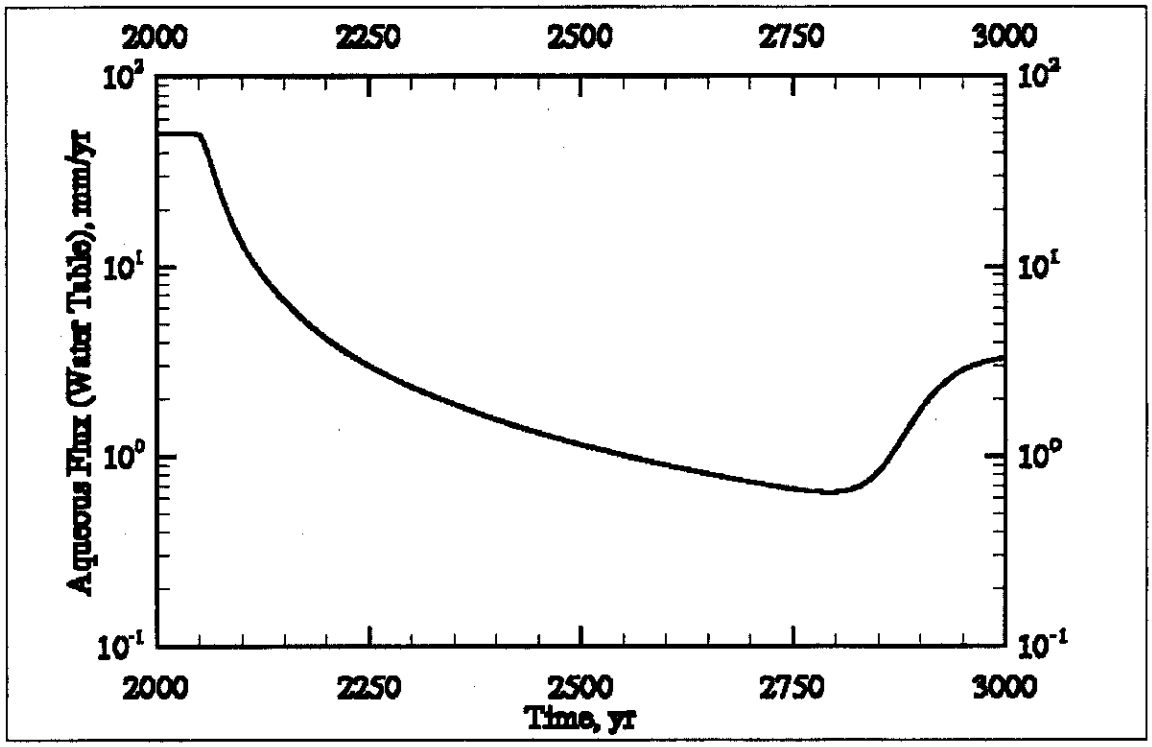


Figure E3.132. Case 9 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

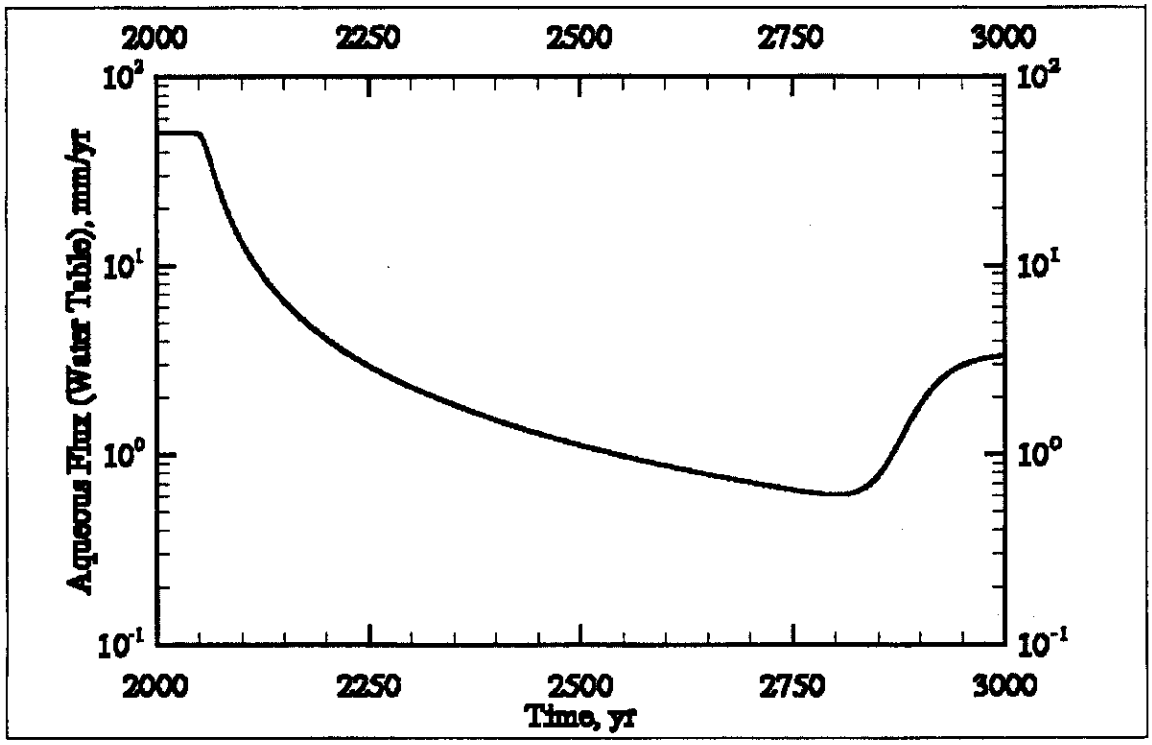


Figure E3.133. Case 9 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

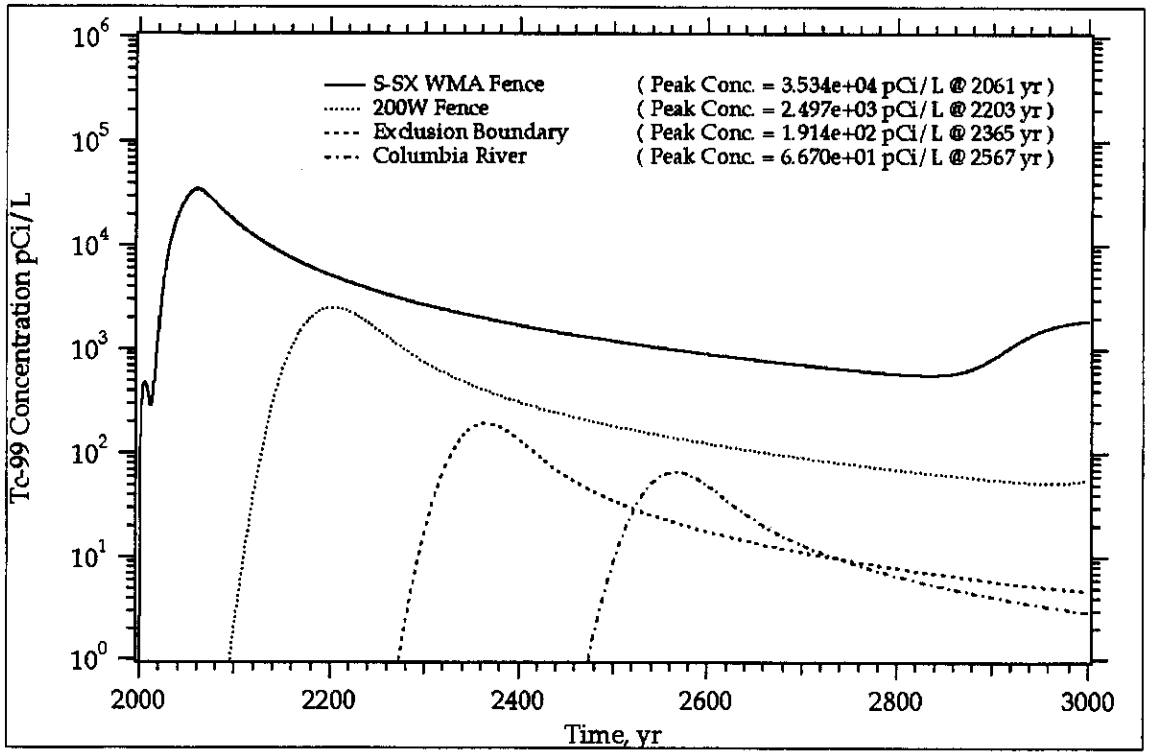


Figure E3.134. Case 9 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

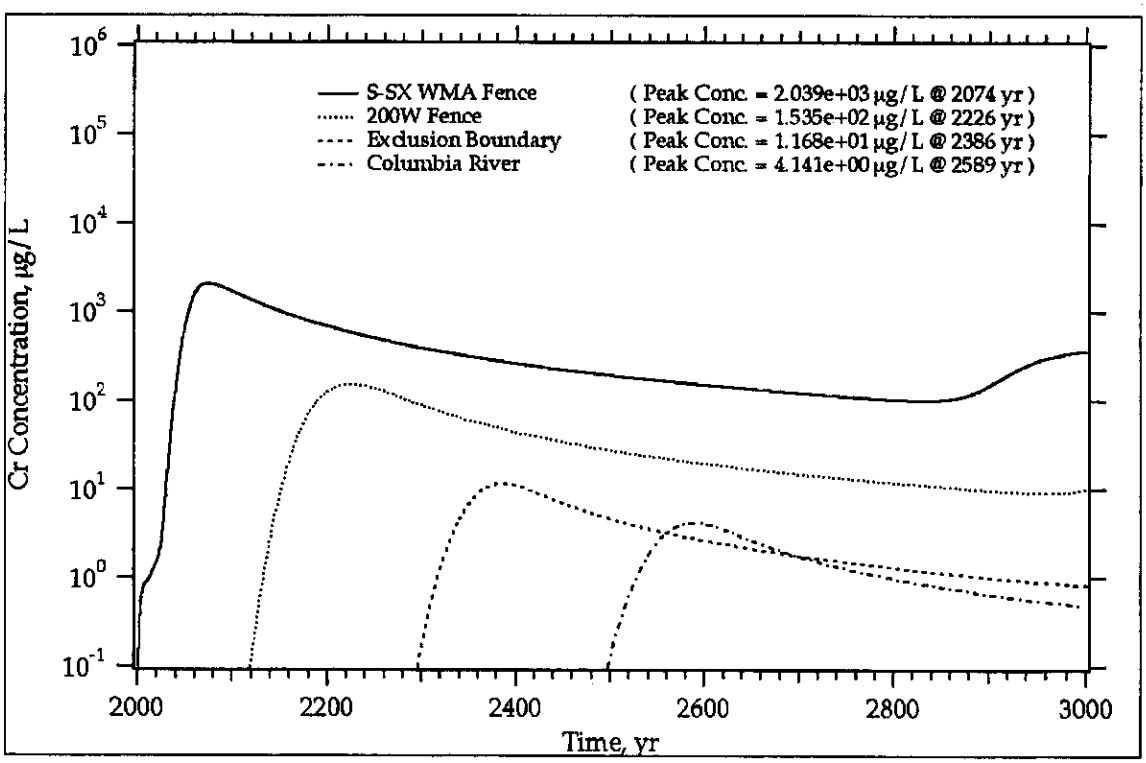
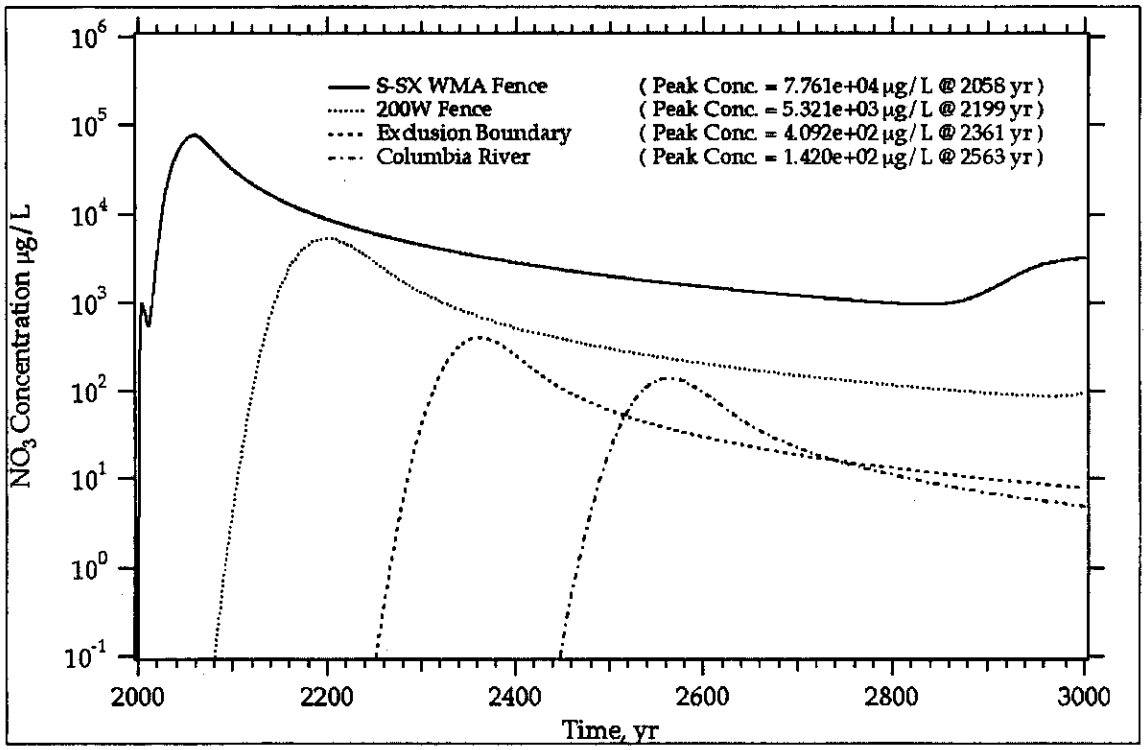


Figure E3.135. Case 9 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.10.0 CASE 10: BASE CASE (30 MM/YR METEORIC RECHARGE)

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only at 30 mm/yr, no water-line leak, no interim barrier, a closure barrier by the year 2040, and a uniform inventory distribution.

Figure E3.136. Case 10 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

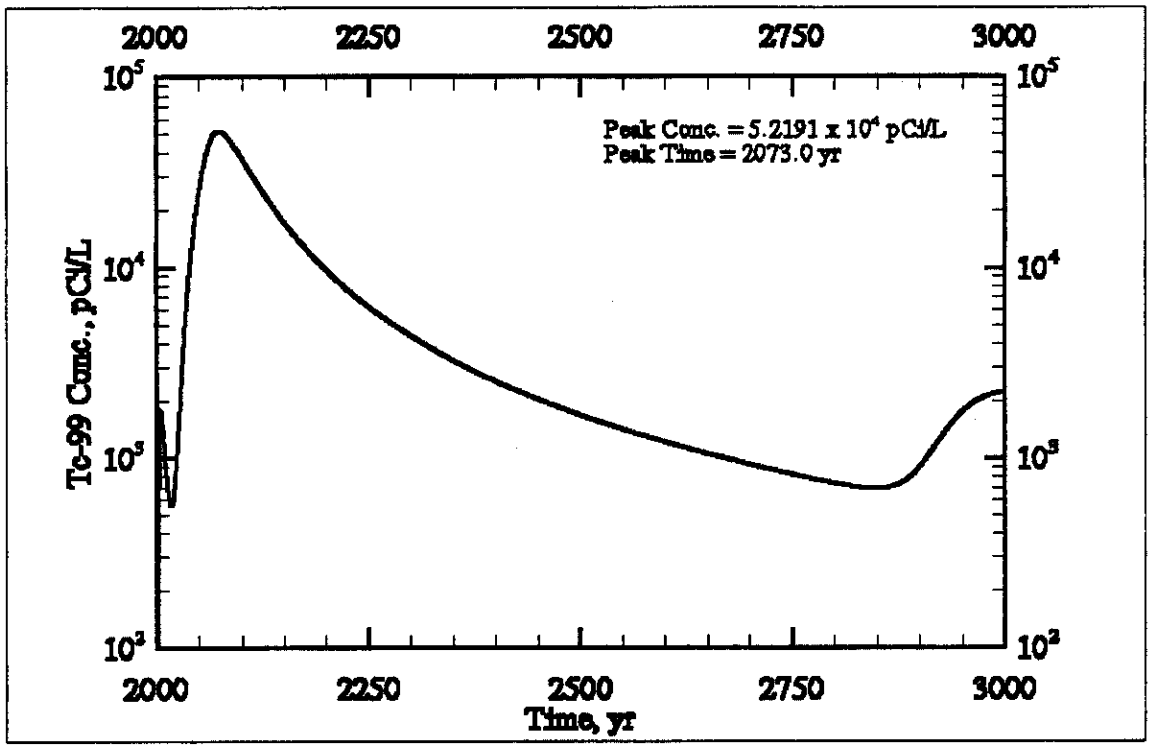


Figure E3.137. Case 10 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

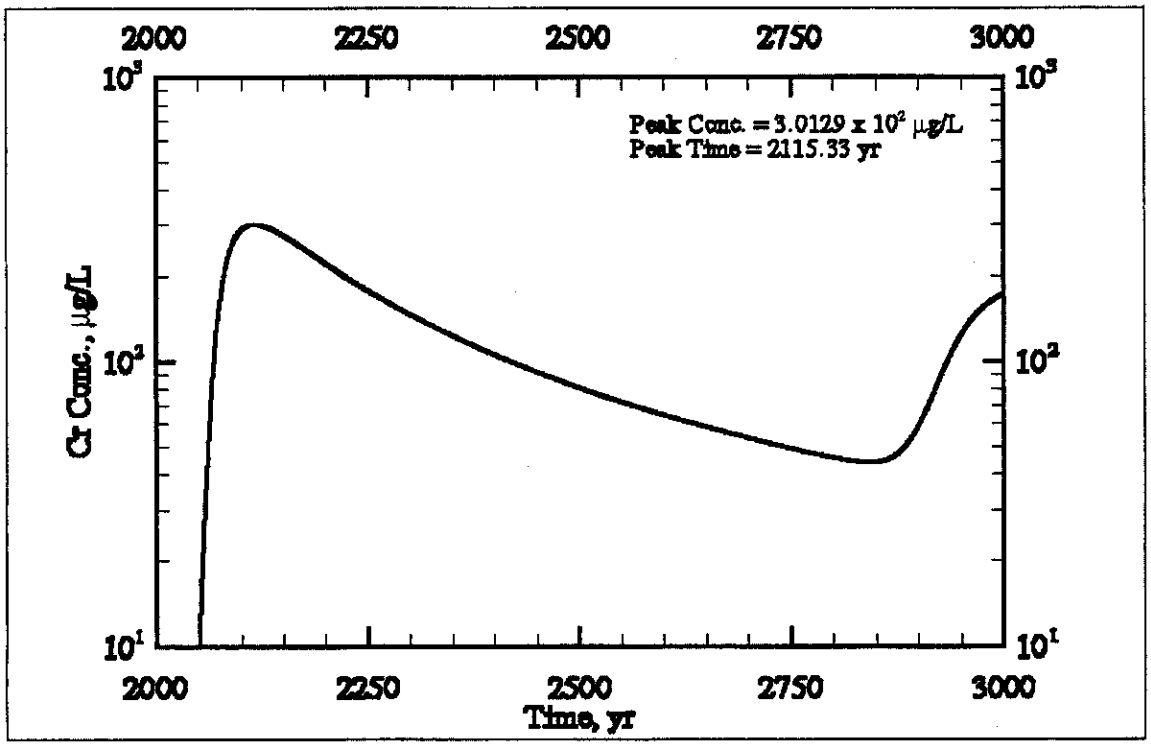


Figure E3.138. Case 10 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

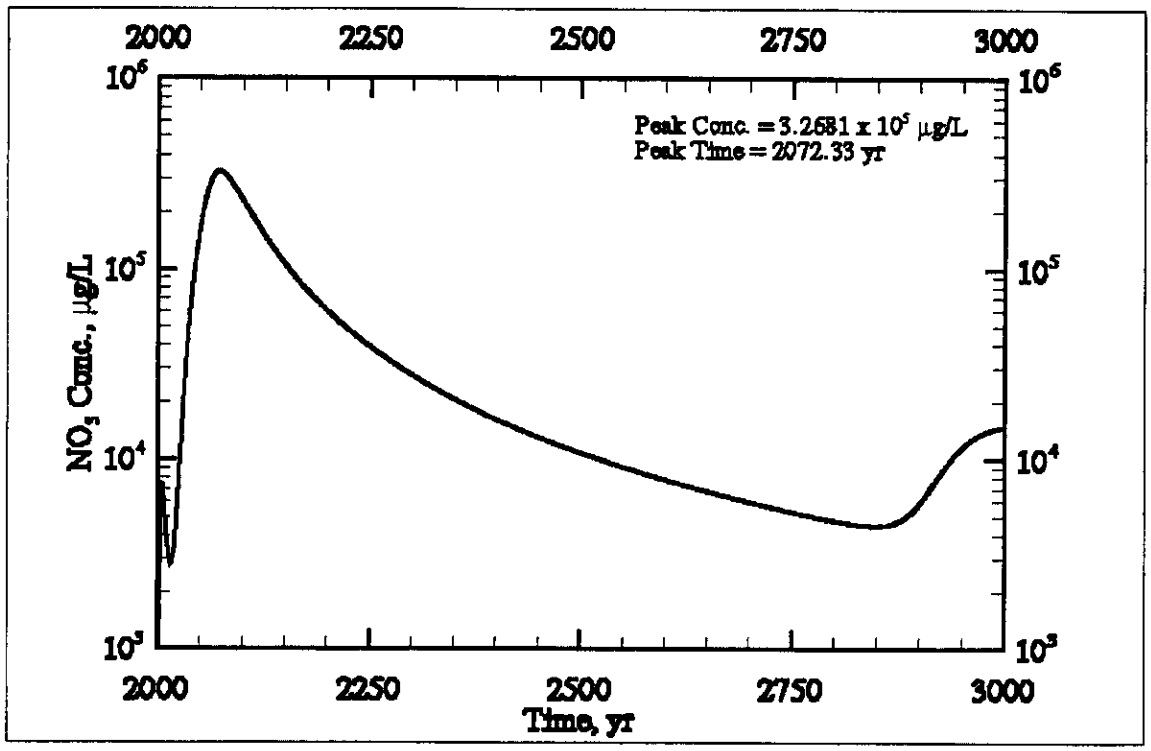


Figure E3.139. Case 10 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

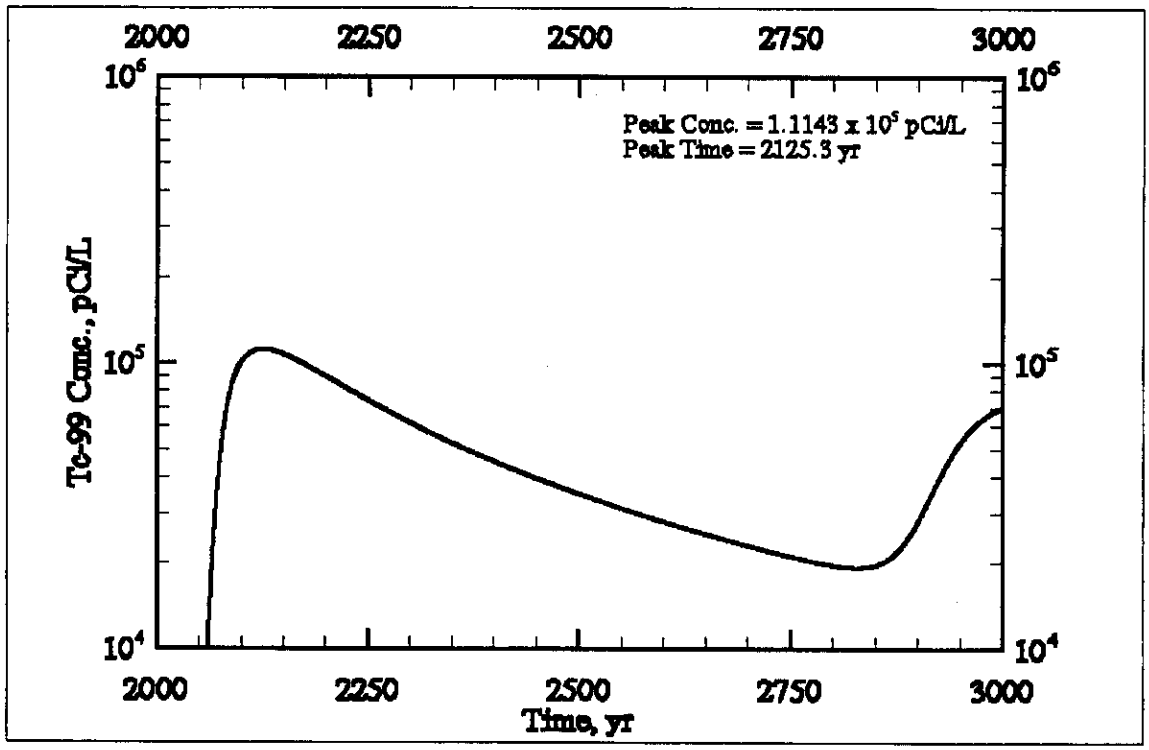


Figure E3.140. Case 10 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

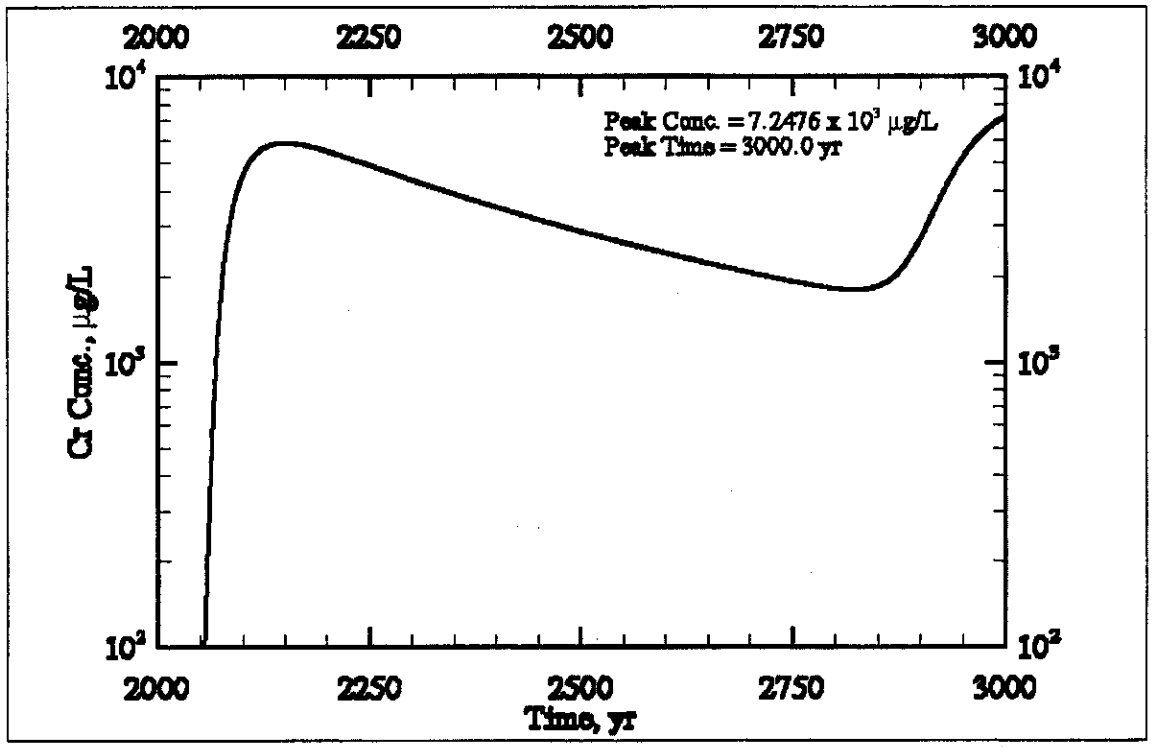


Figure E3.141. Case 10 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

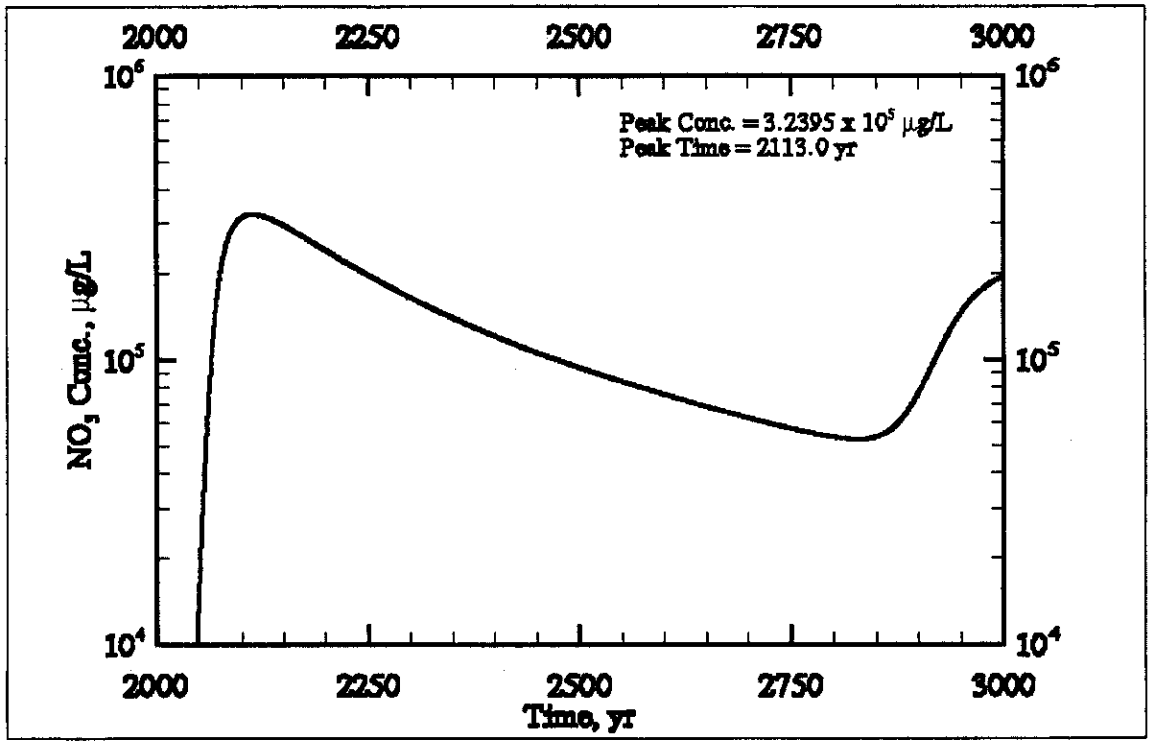


Figure E3.142. Case 10 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

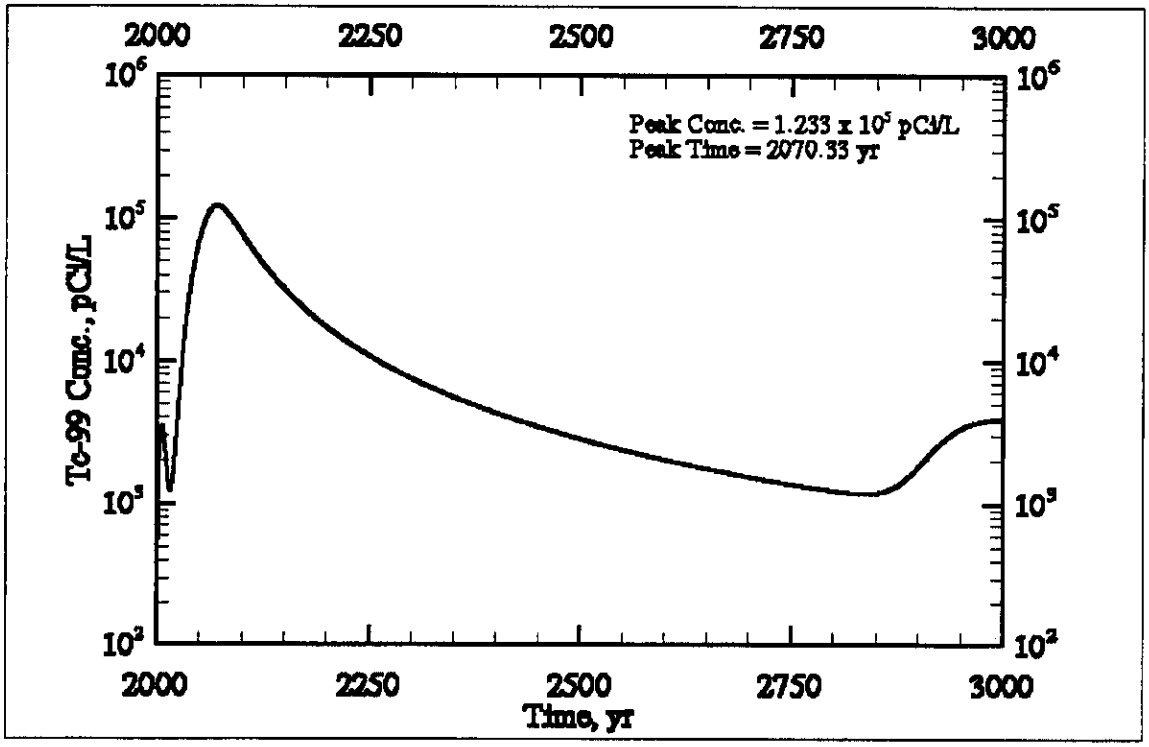


Figure E3.143. Case 10 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

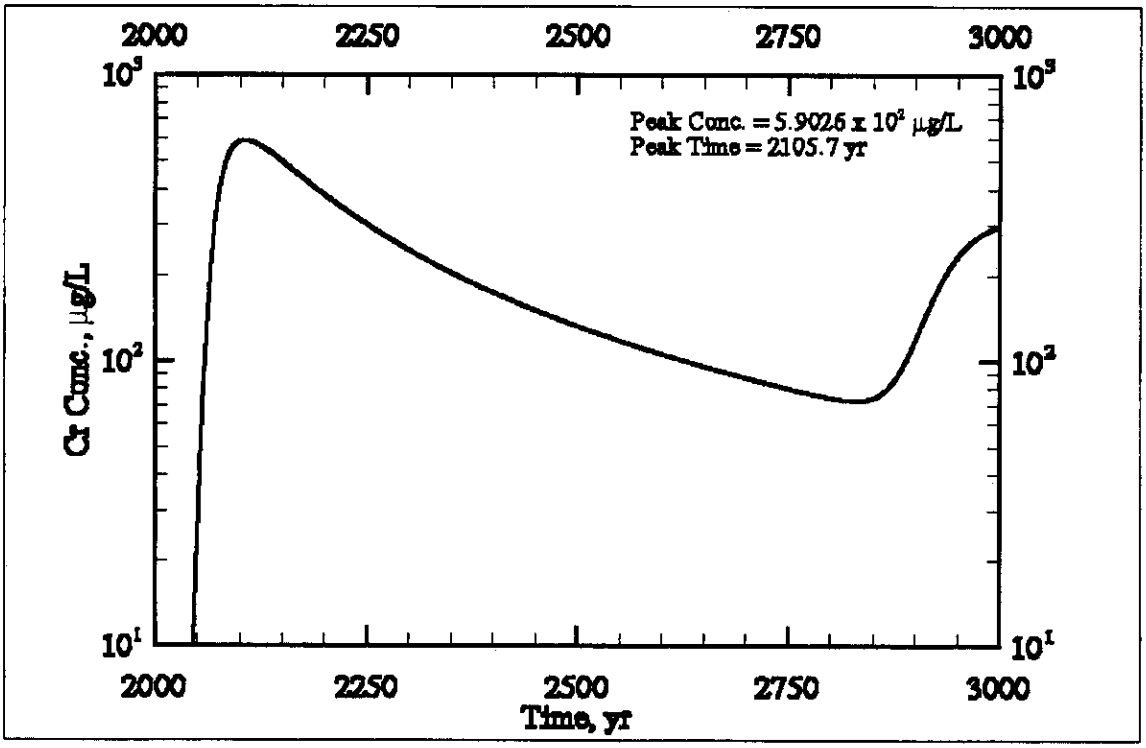


Figure E3.144. Case 10 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

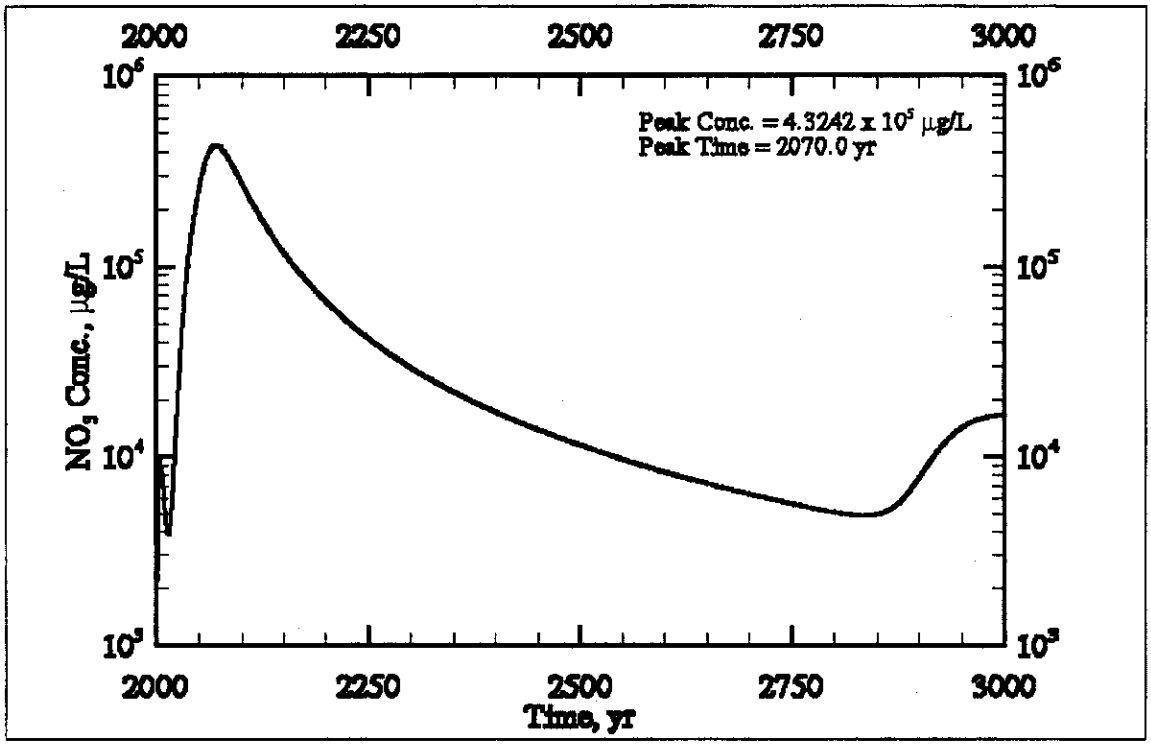


Figure E3.145. Case 10 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

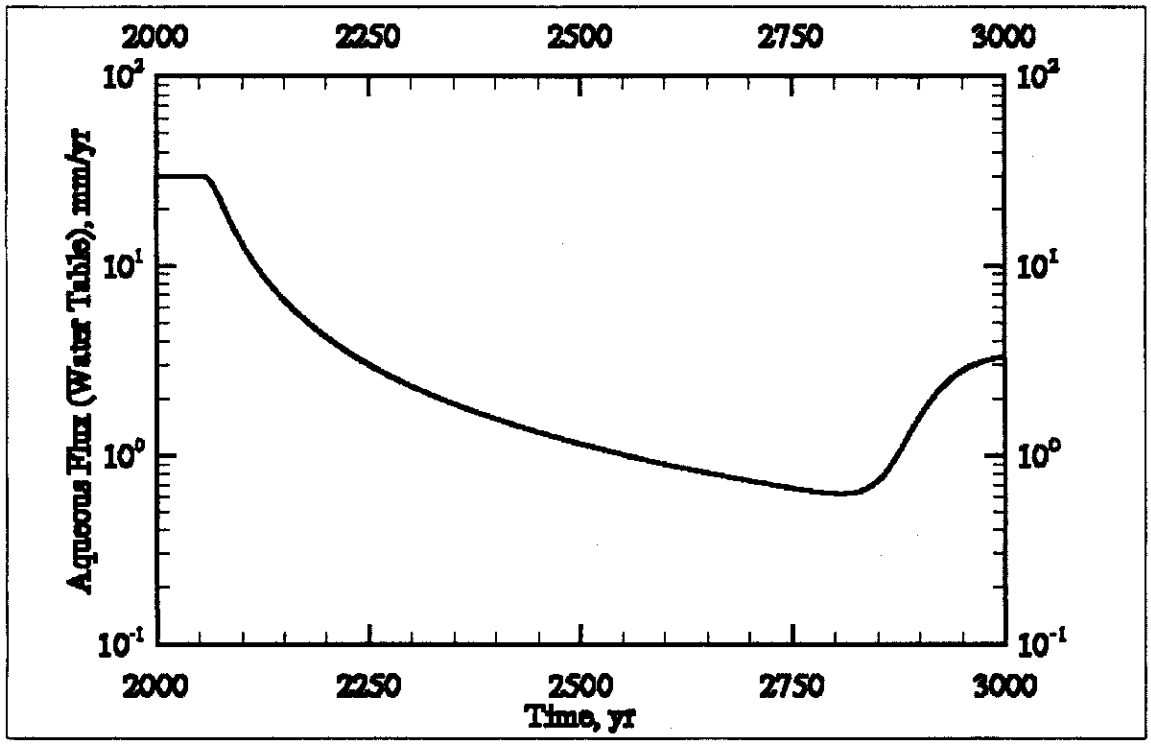


Figure E3.146. Case 10 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

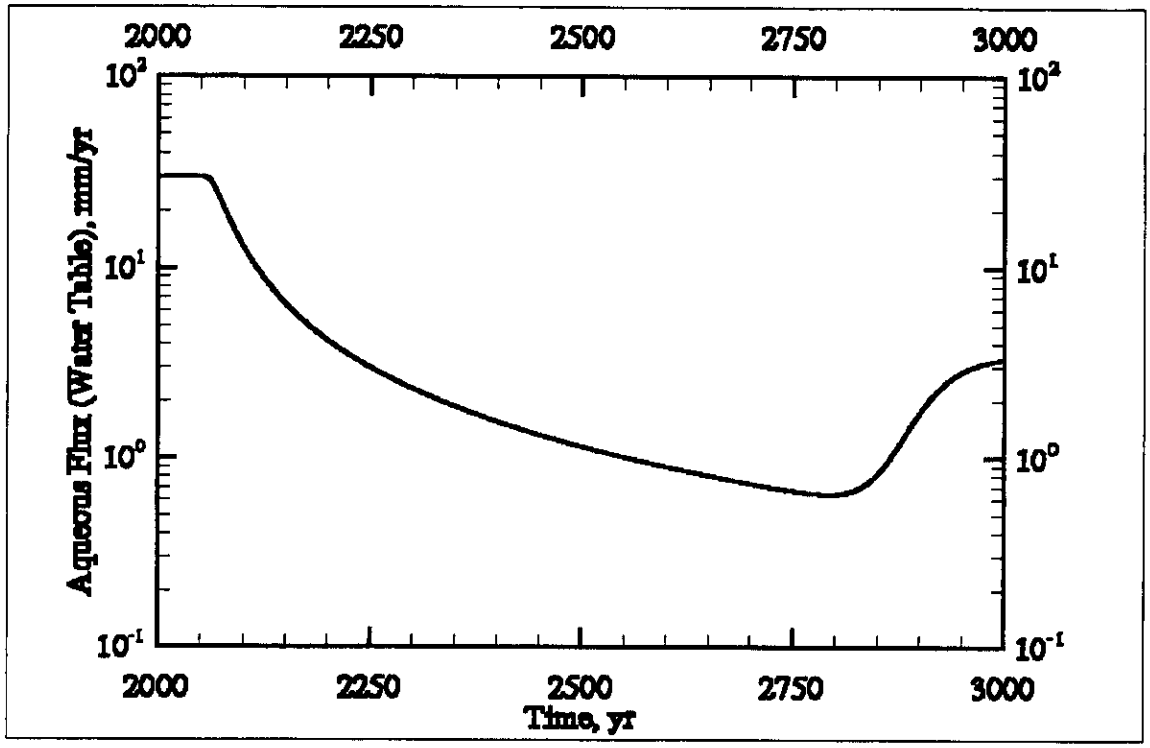


Figure E3.147. Case 10 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

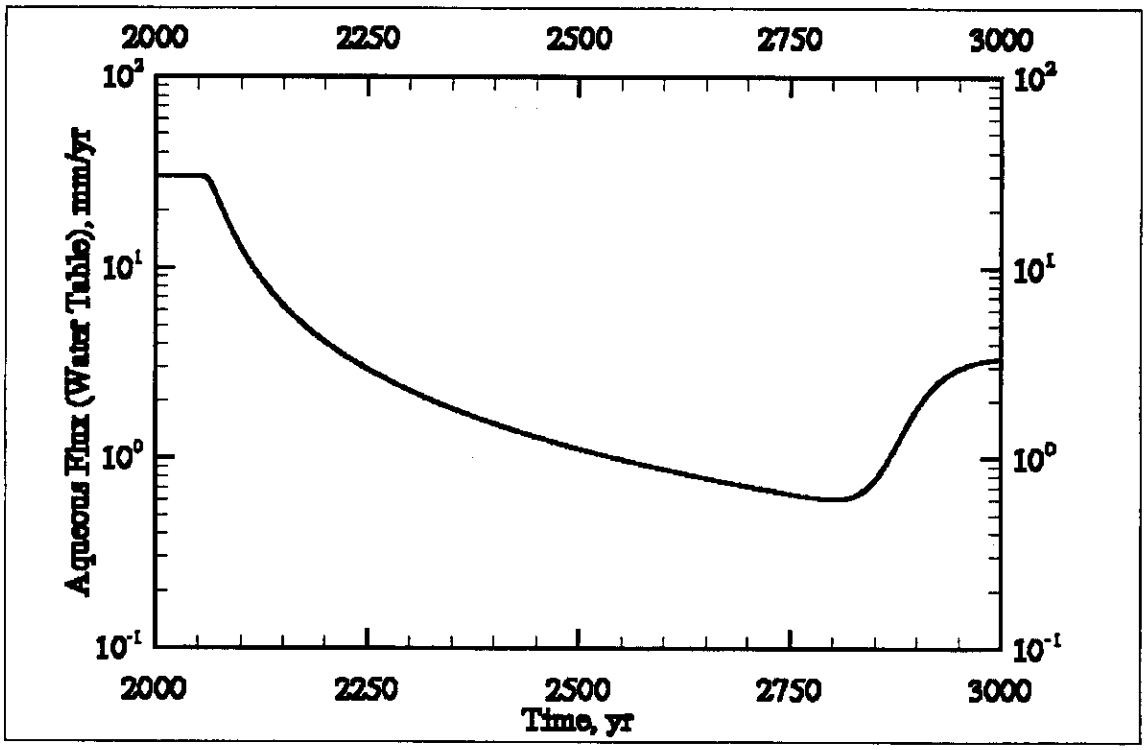


Figure E3.148. Case 10 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

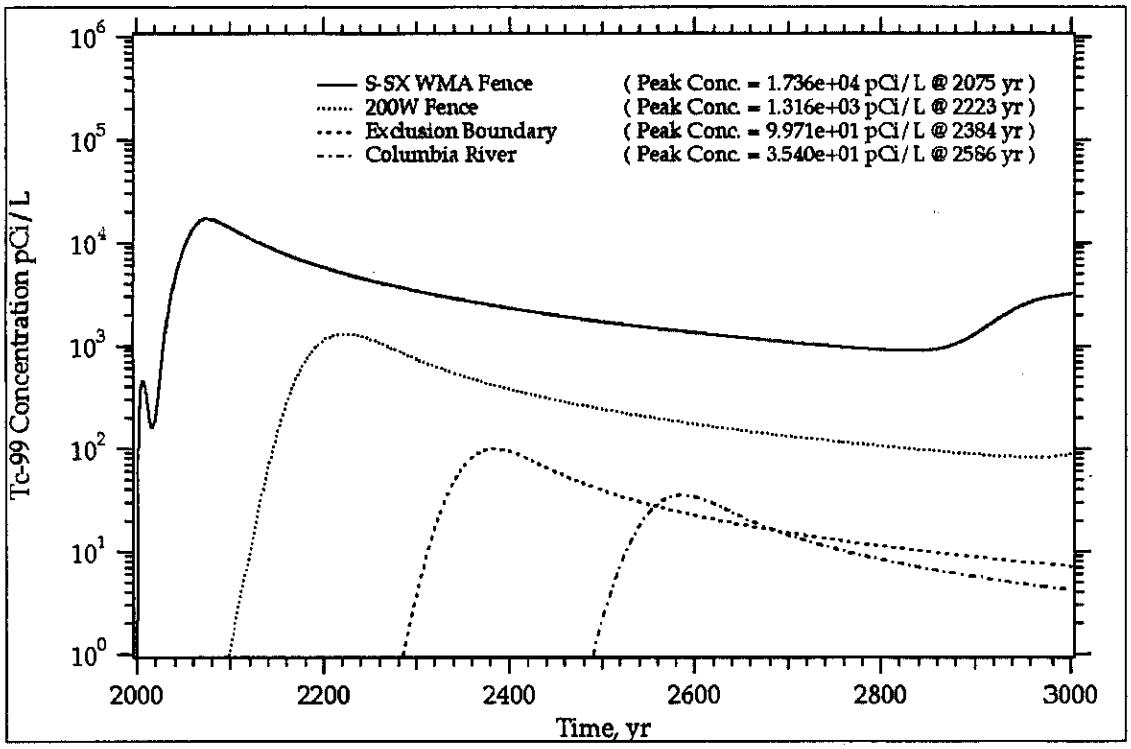


Figure E3.149. Case 10 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

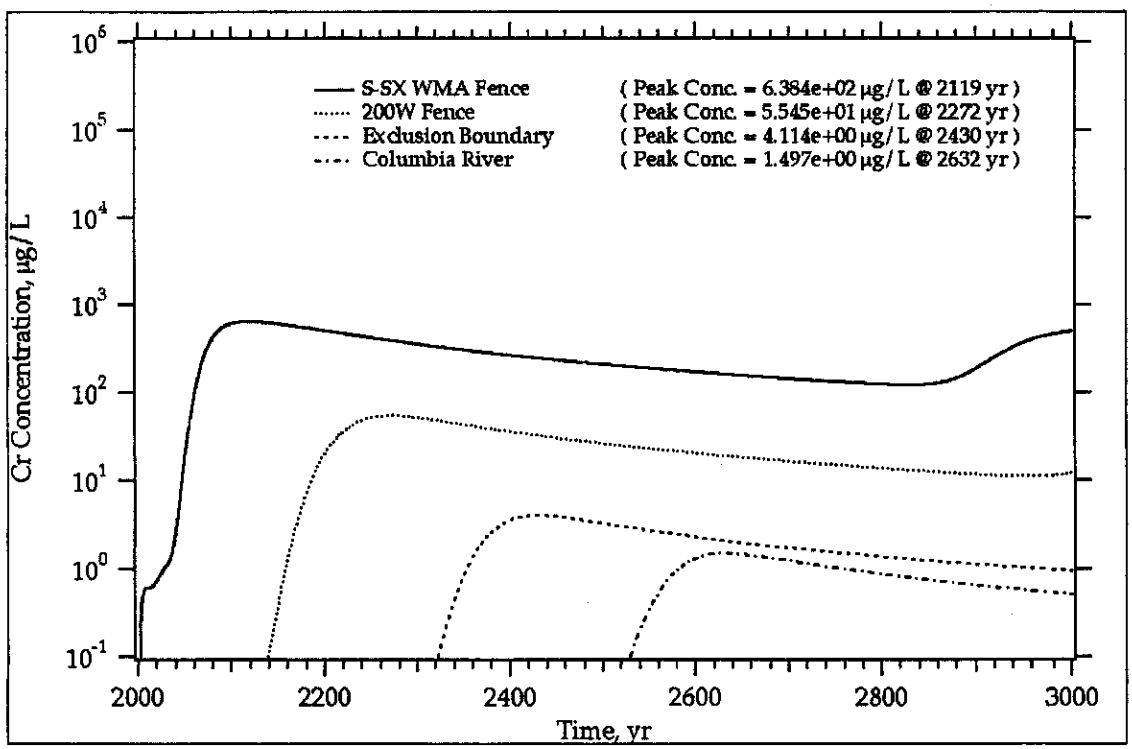
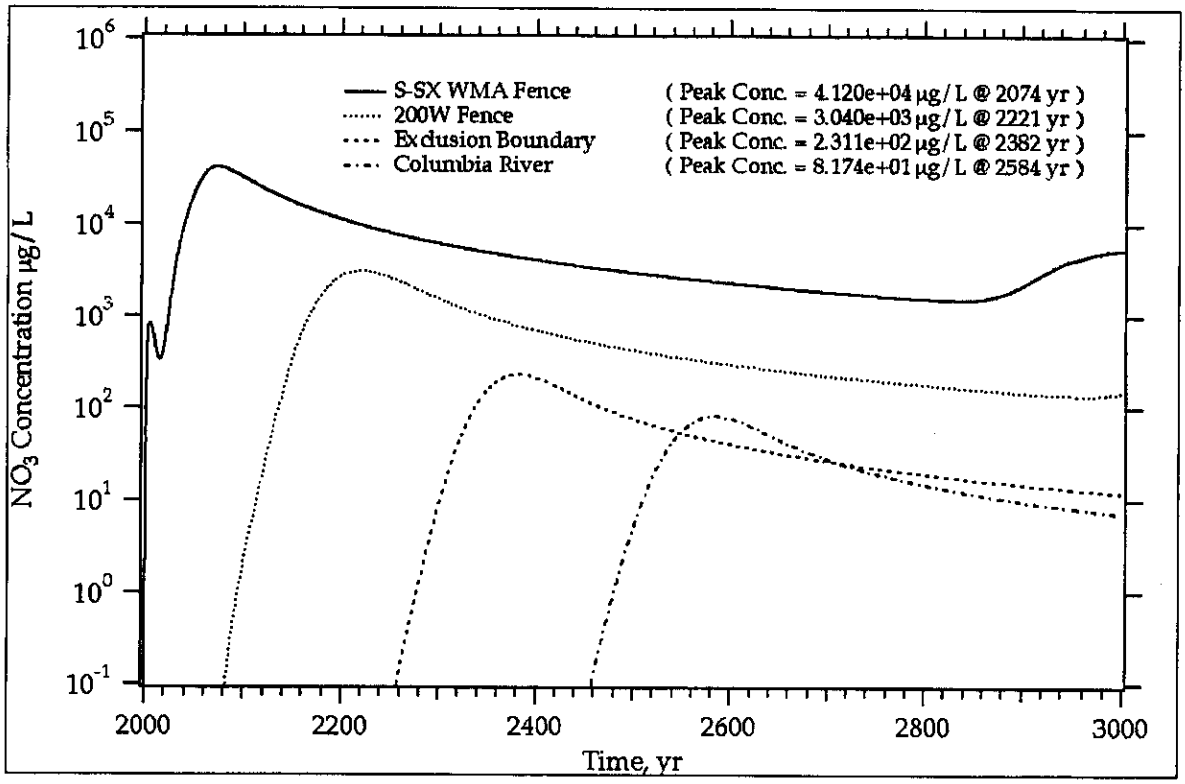


Figure E3.150. Case 10 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.11.0 CASE 11: BASE CASE (10 MM/YR METEORIC RECHARGE)

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only at 10 mm/yr, no water-line leak, no interim barrier, a closure barrier by the year 2040, and a uniform inventory distribution.

Figure E3.151. Case 11 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

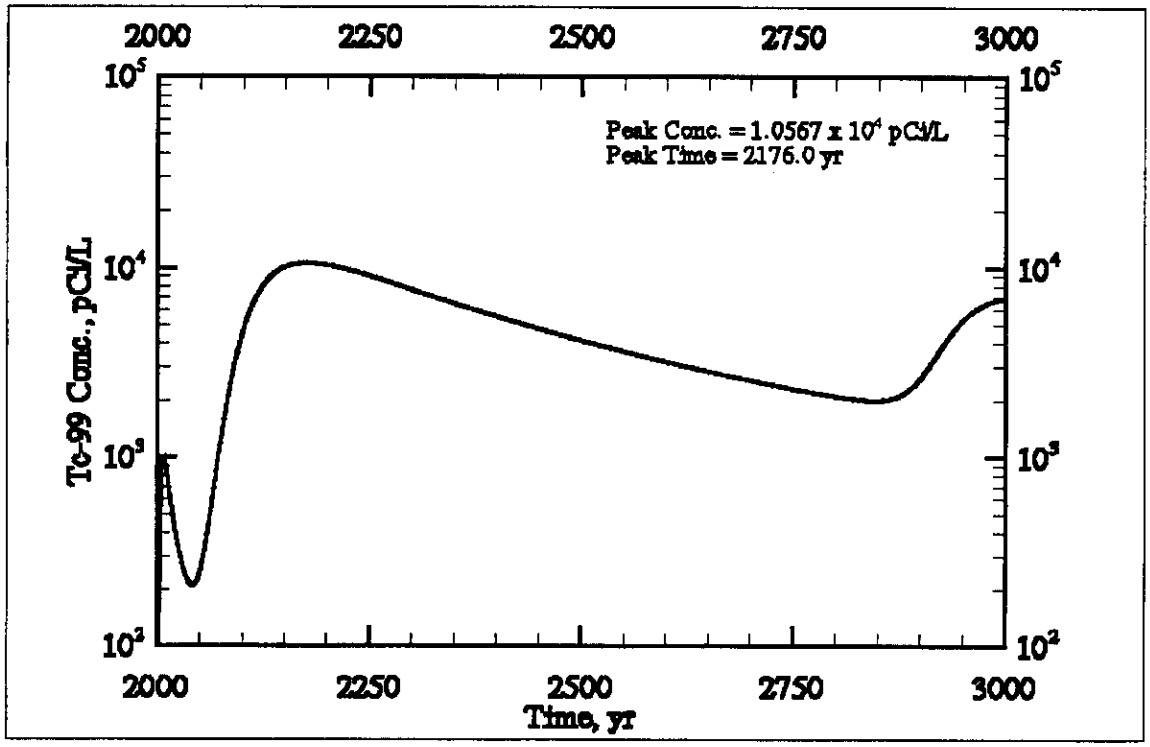


Figure E3.152. Case 11 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

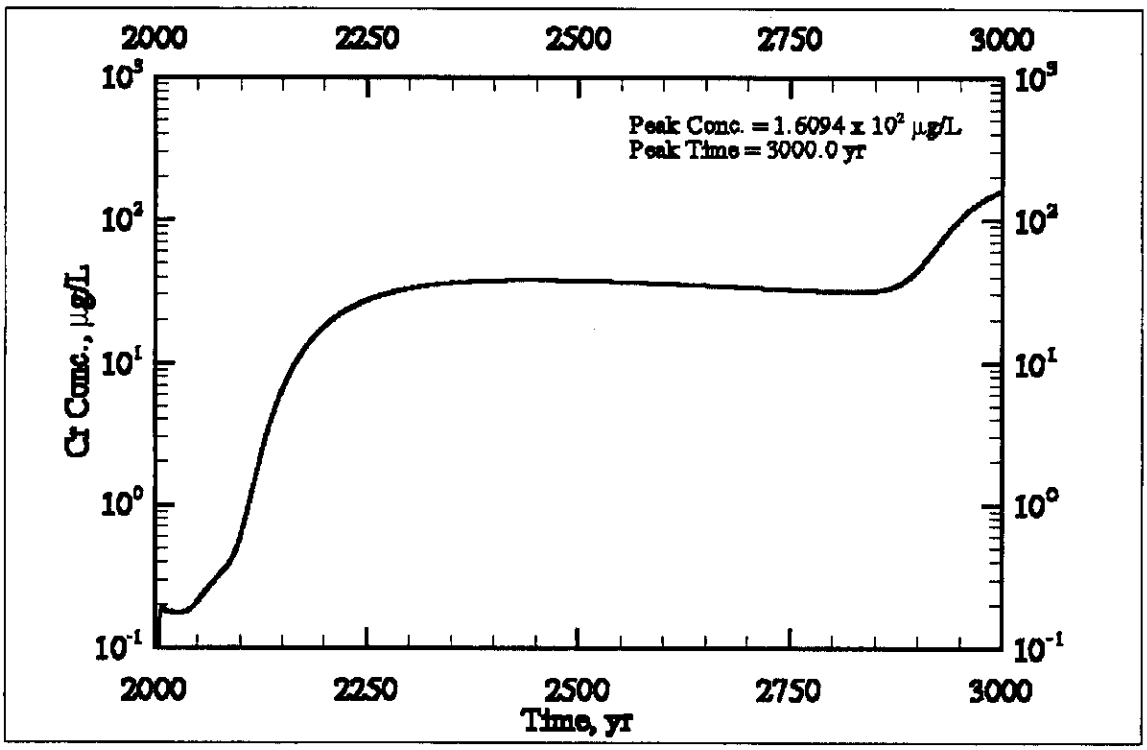


Figure E3.153. Case 11 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

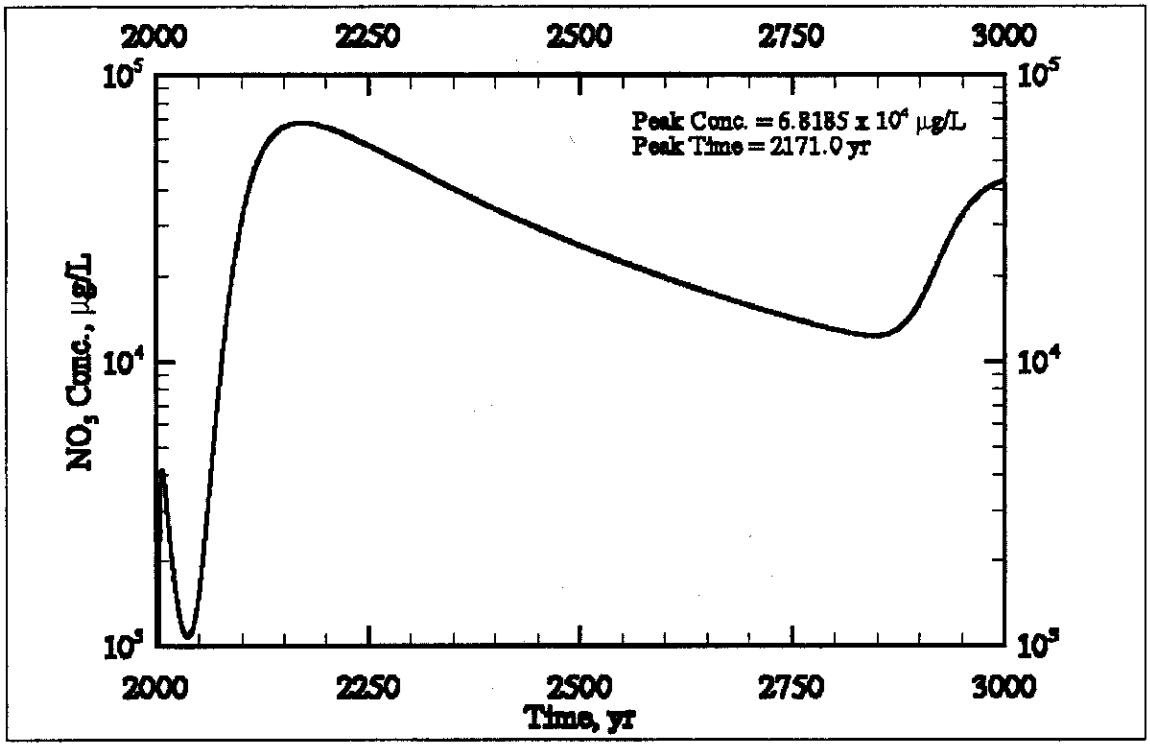


Figure E3.154. Case 11 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

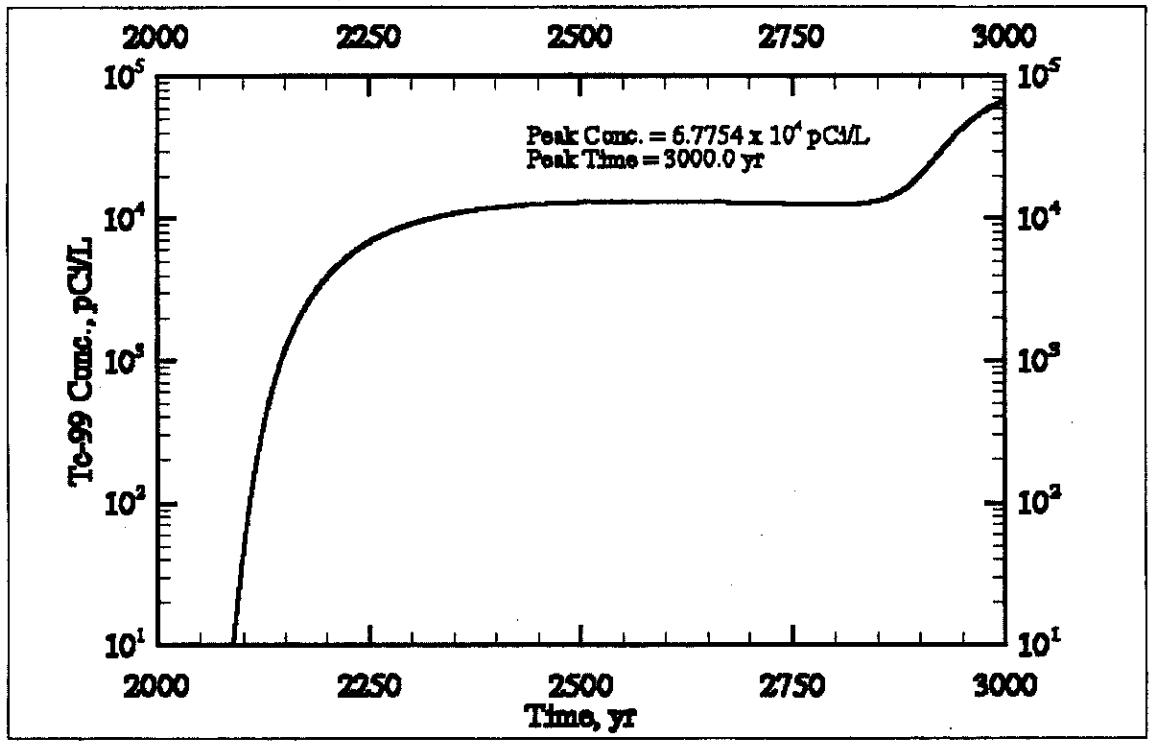


Figure E3.155. Case 11 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

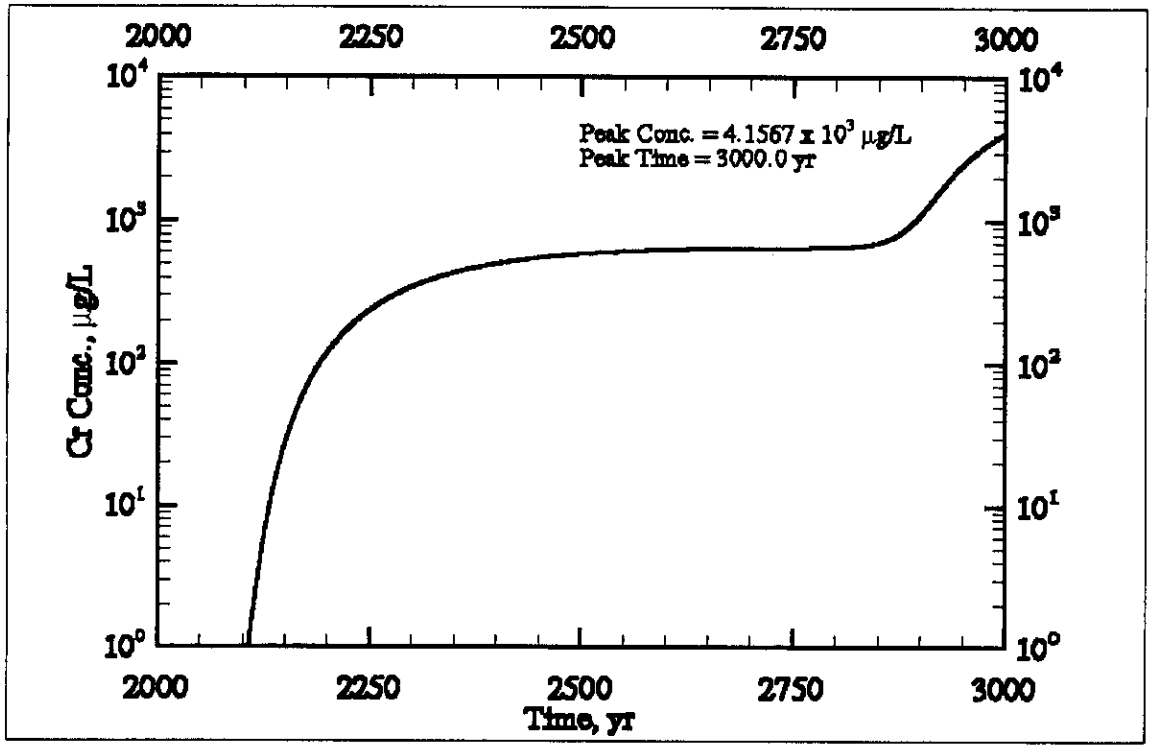


Figure E3.156. Case 11 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

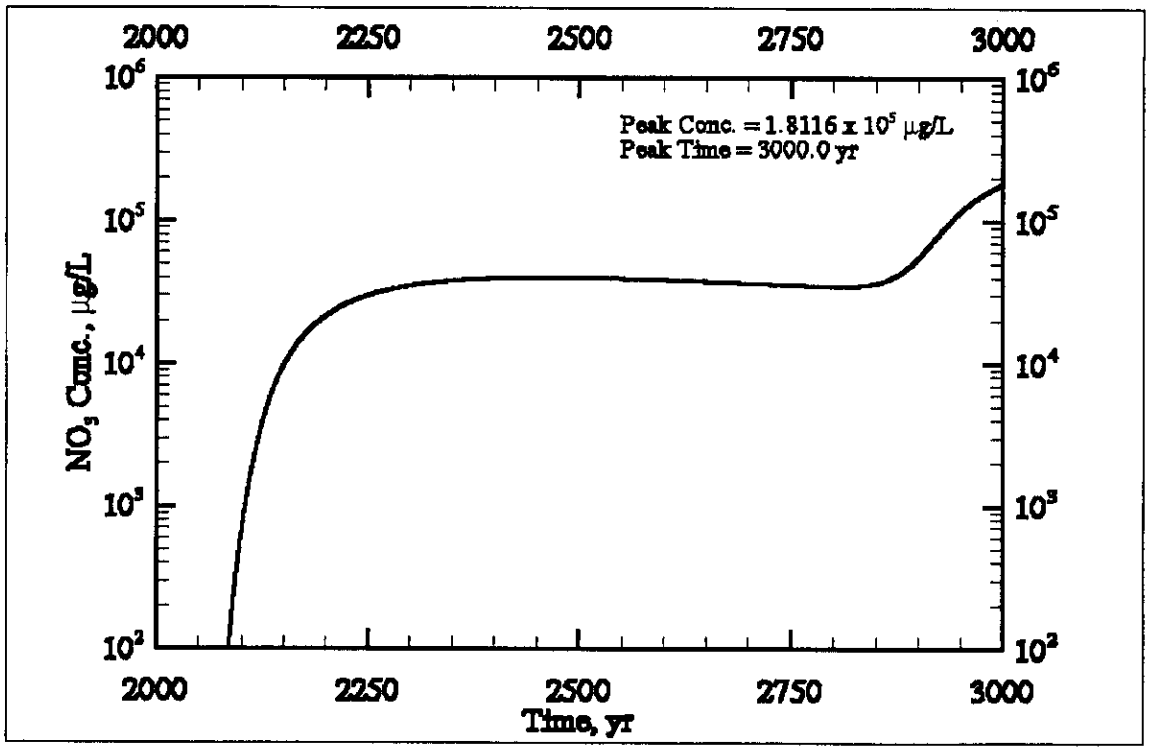


Figure E3.157. Case 11 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

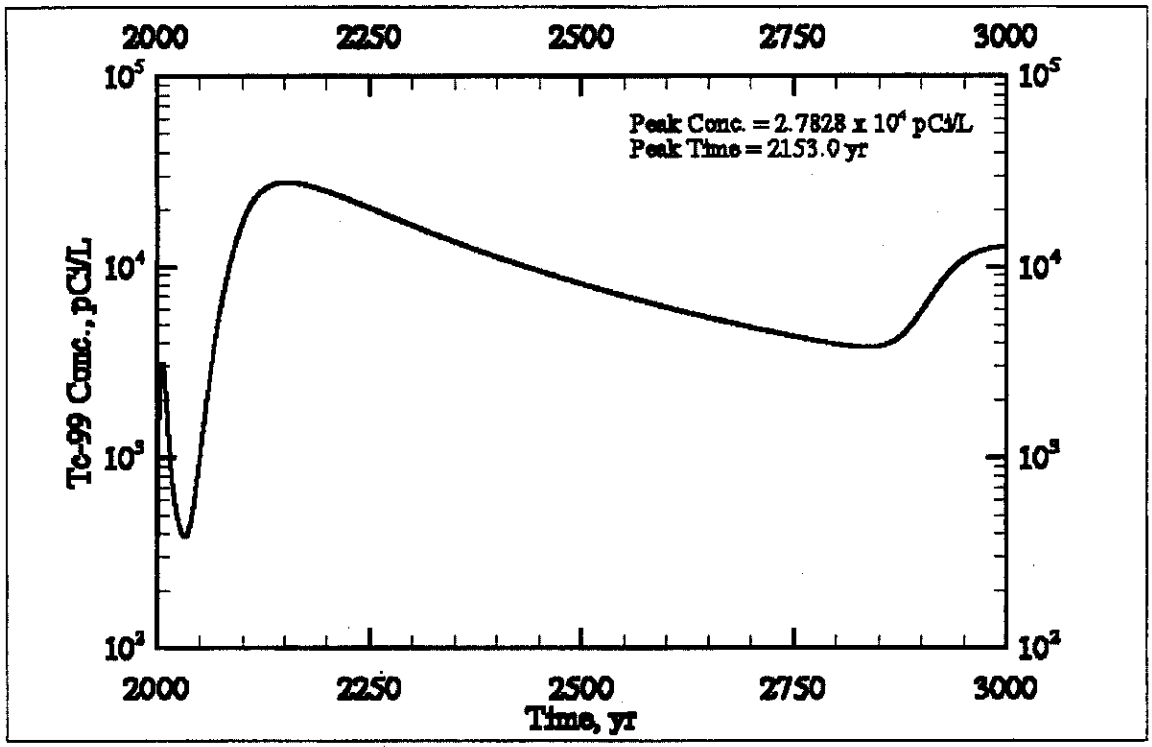


Figure E3.158. Case 11 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

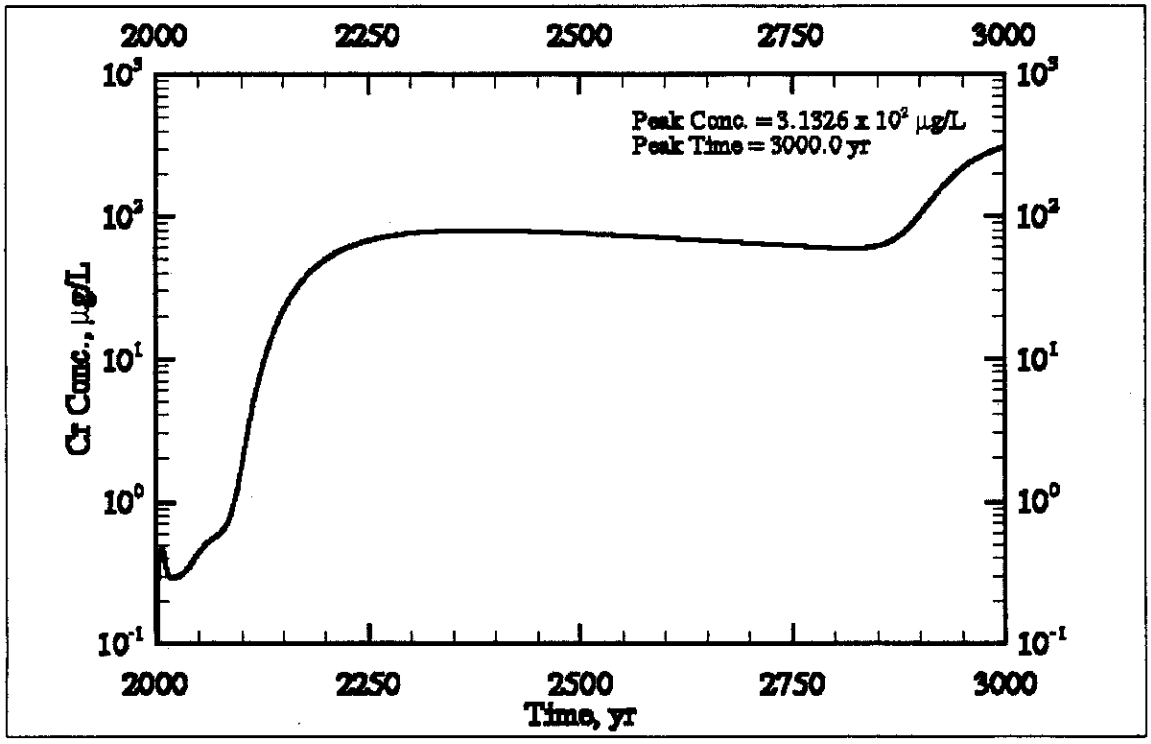


Figure E3.159. Case 11 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

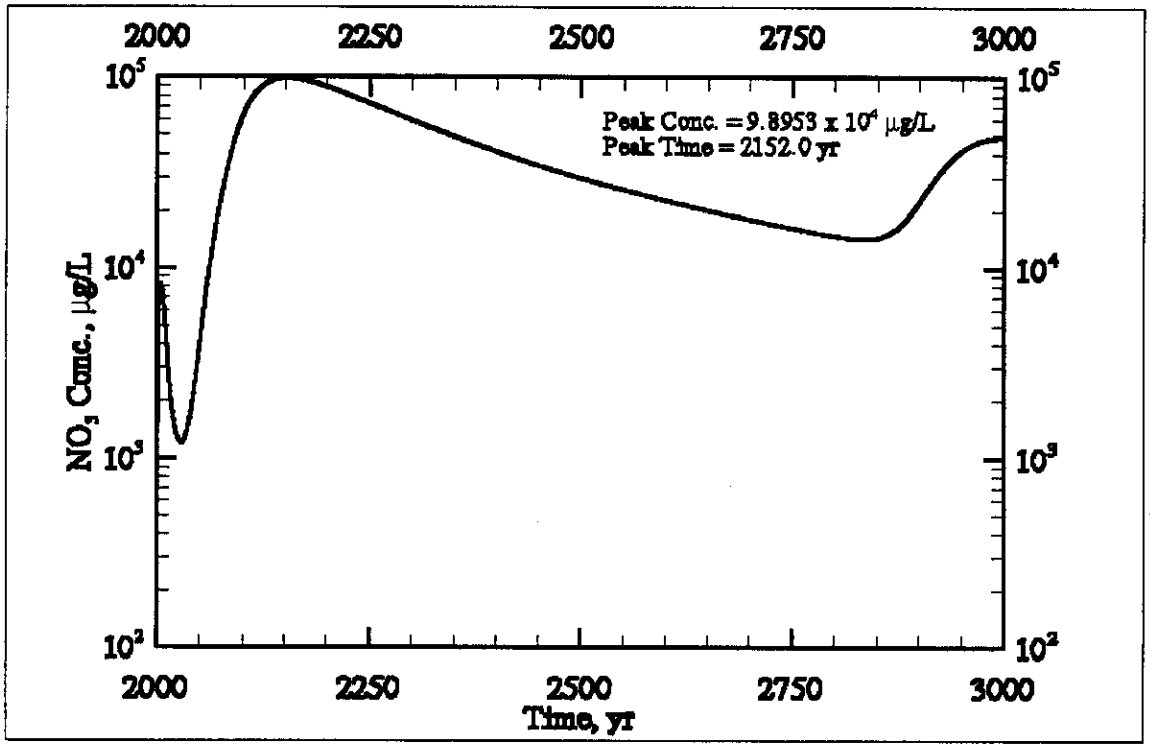


Figure E3.160. Case 11 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

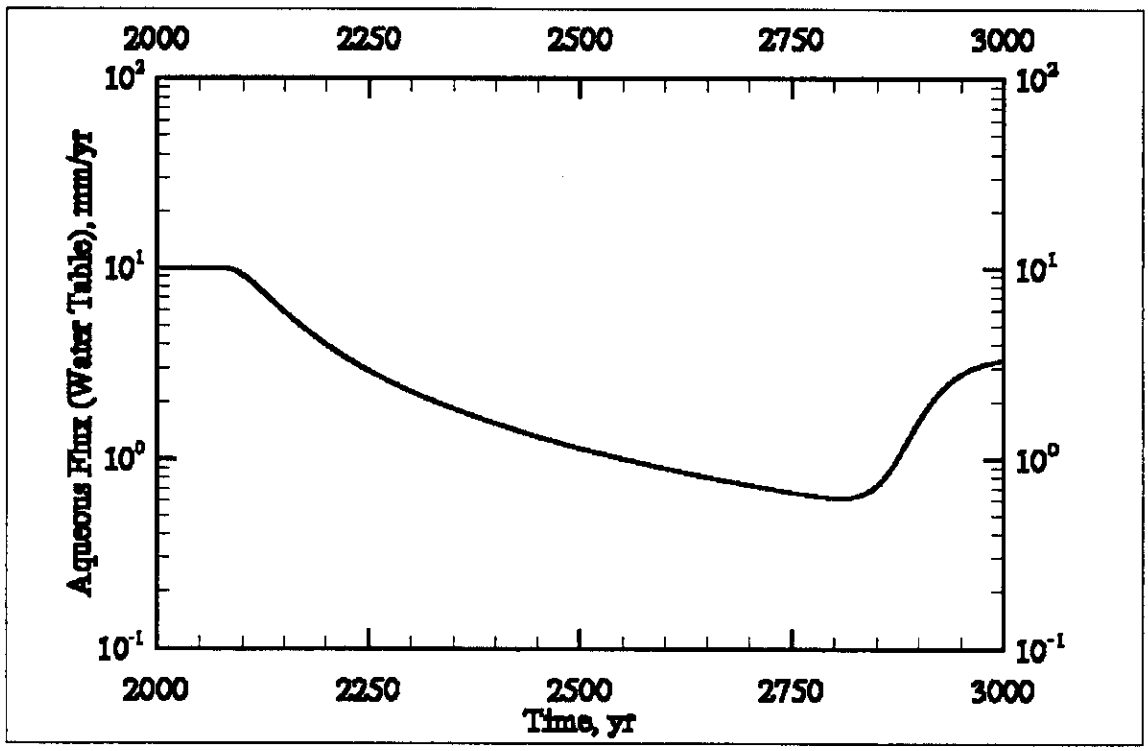


Figure E3.161. Case 11 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

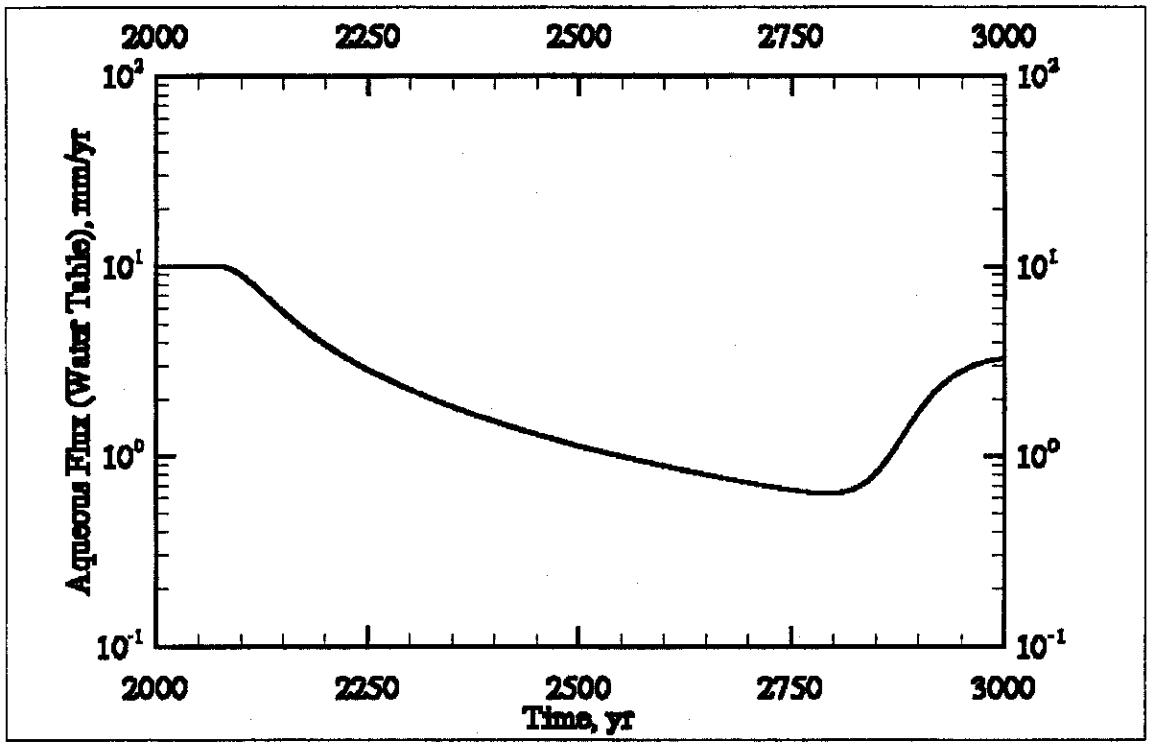


Figure E3.162. Case 11 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

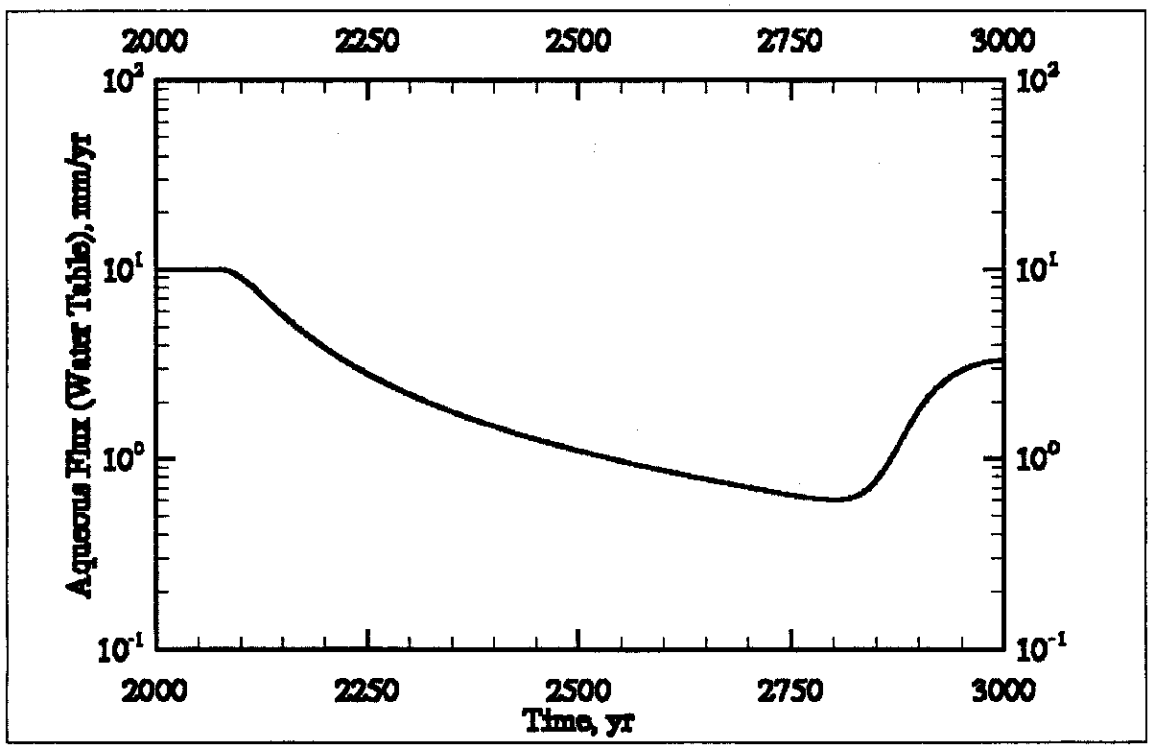


Figure E3.163. Case 11 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

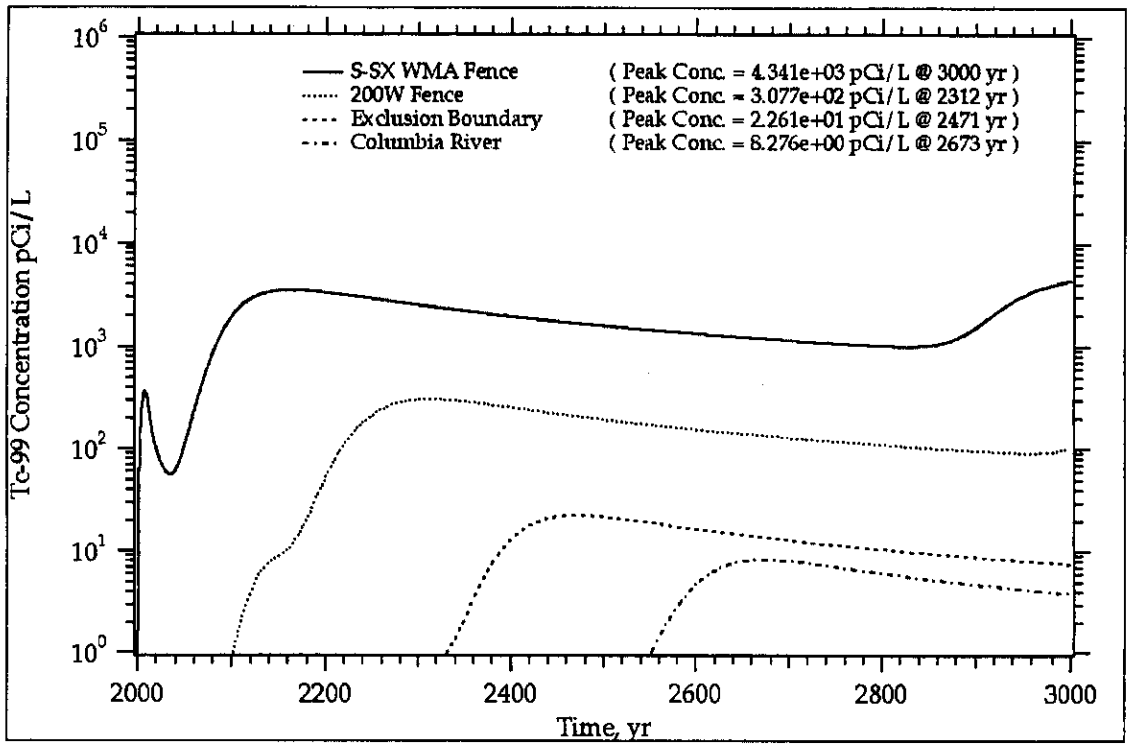


Figure E3.164. Case 11 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

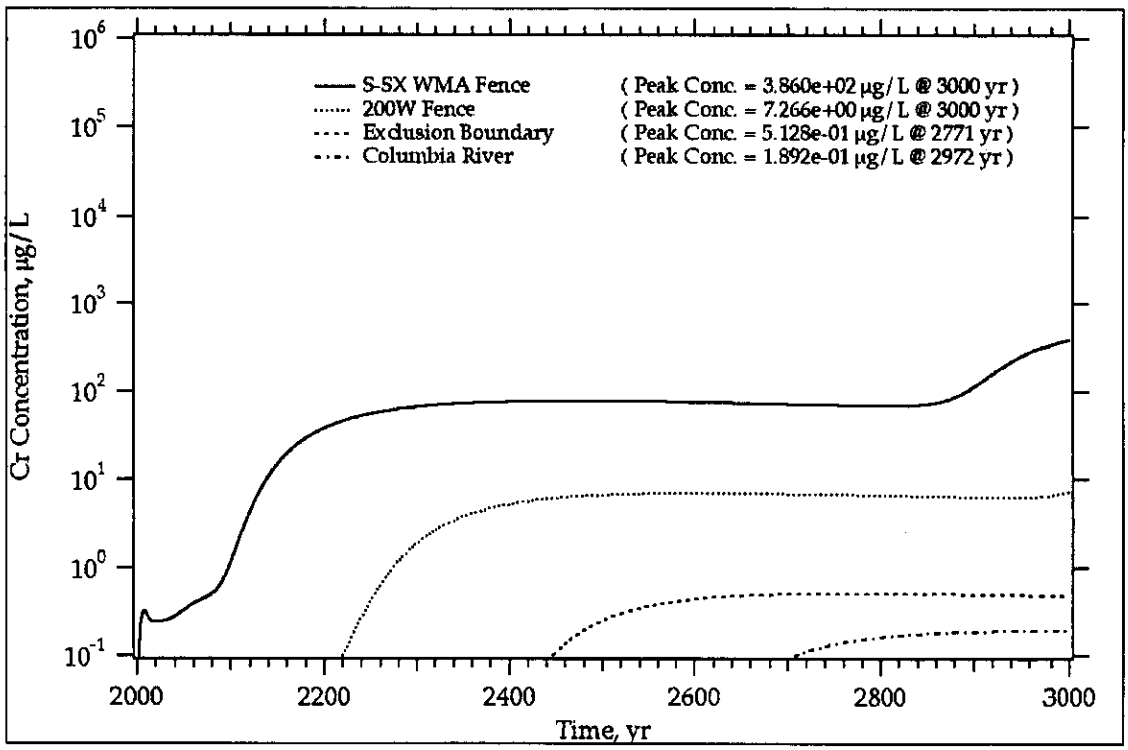
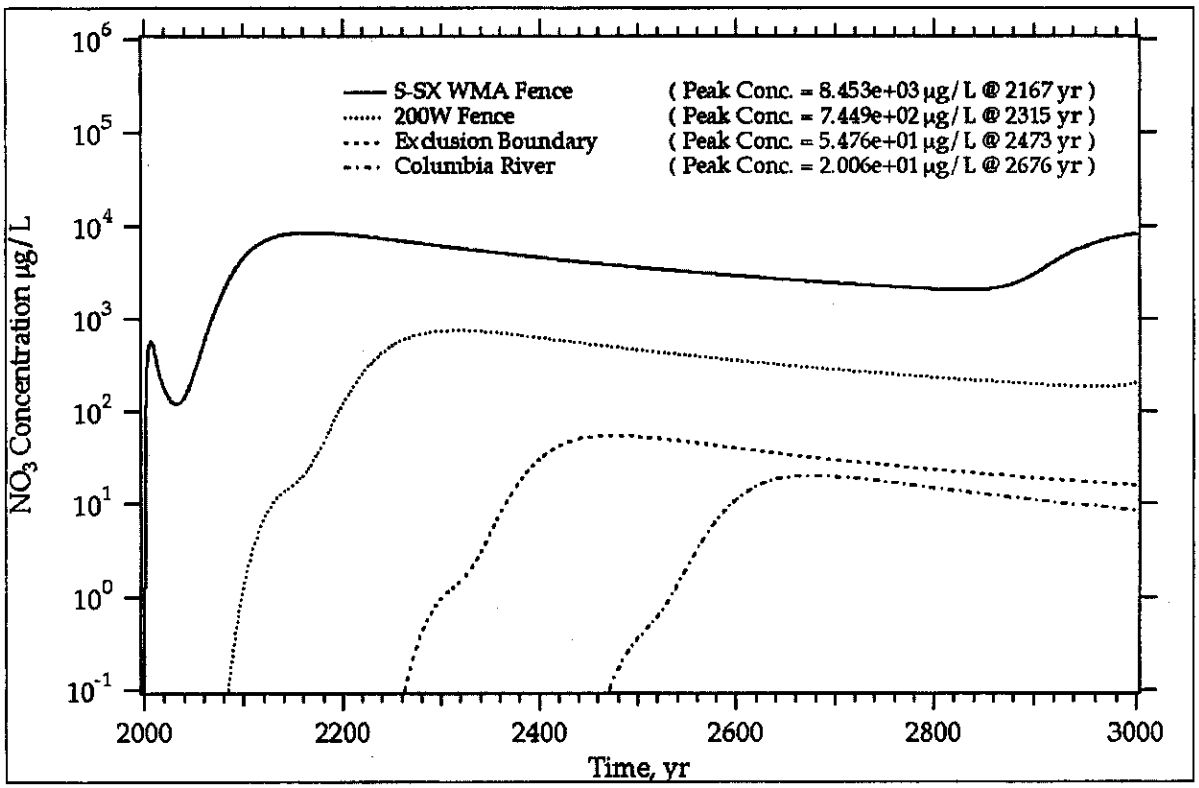


Figure E3.165. Case 11 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.12.0 CASE 12: ALTERNATE UNIFORM INVENTORY DISTRIBUTION

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration only at 100 mm/yr, no water-line leak, no interim barrier, a closure barrier by the year 2040, and an alternate uniform inventory distribution.

Figure E3.166. Case 12 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

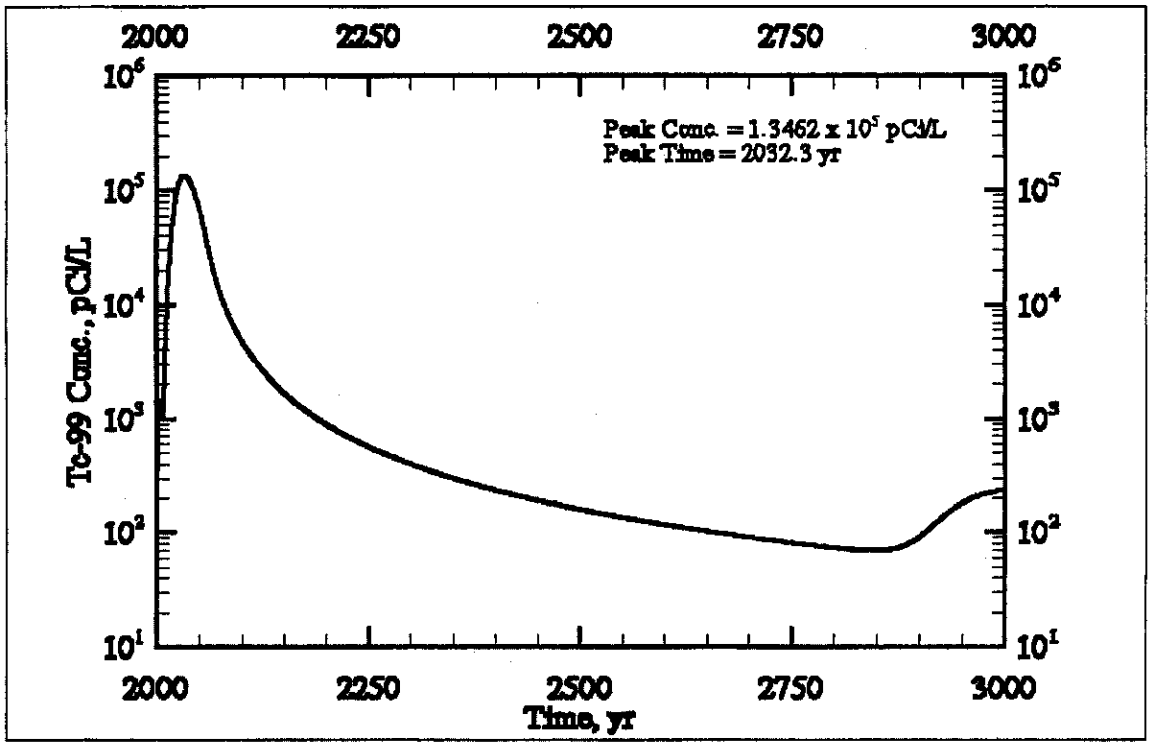


Figure E3.167. Case 12 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

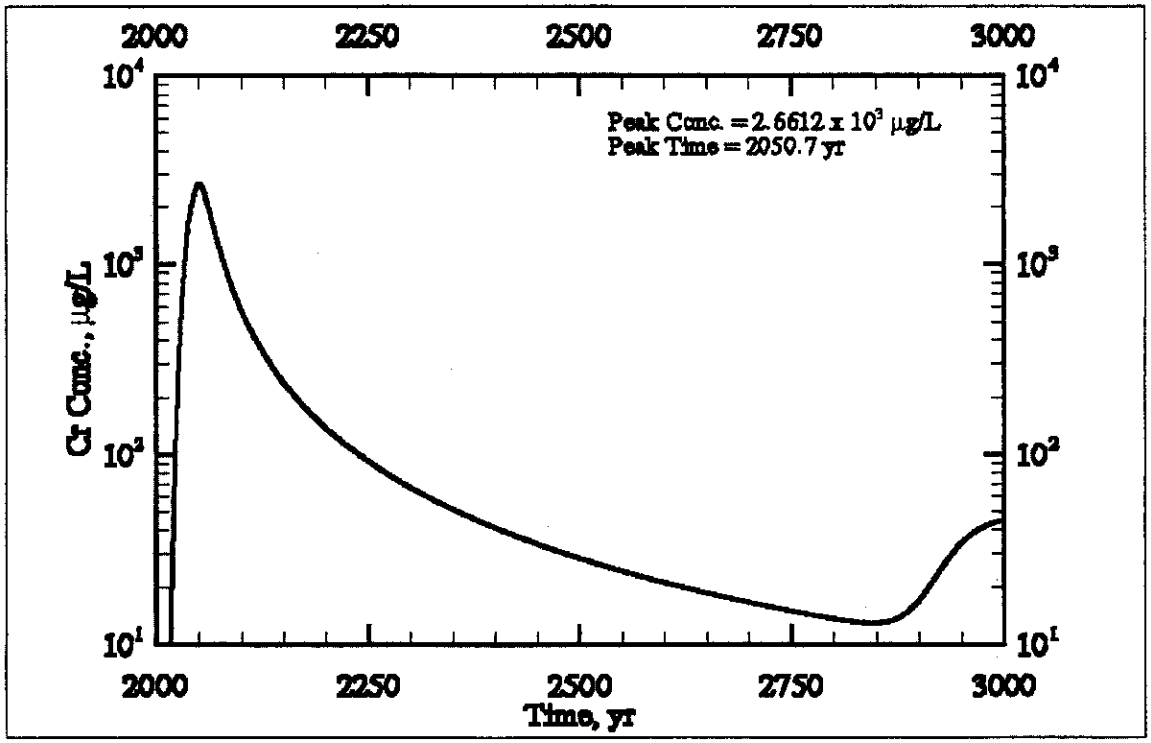


Figure E3.168. Case 12 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

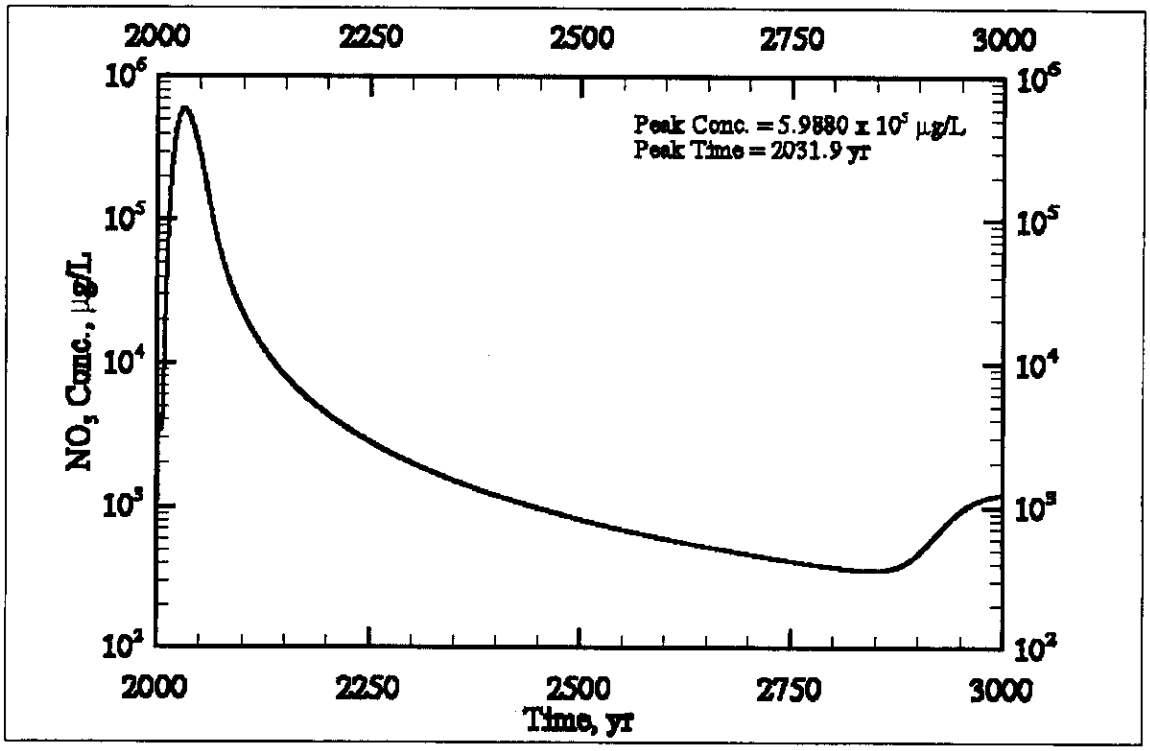


Figure E3.169. Case 12 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

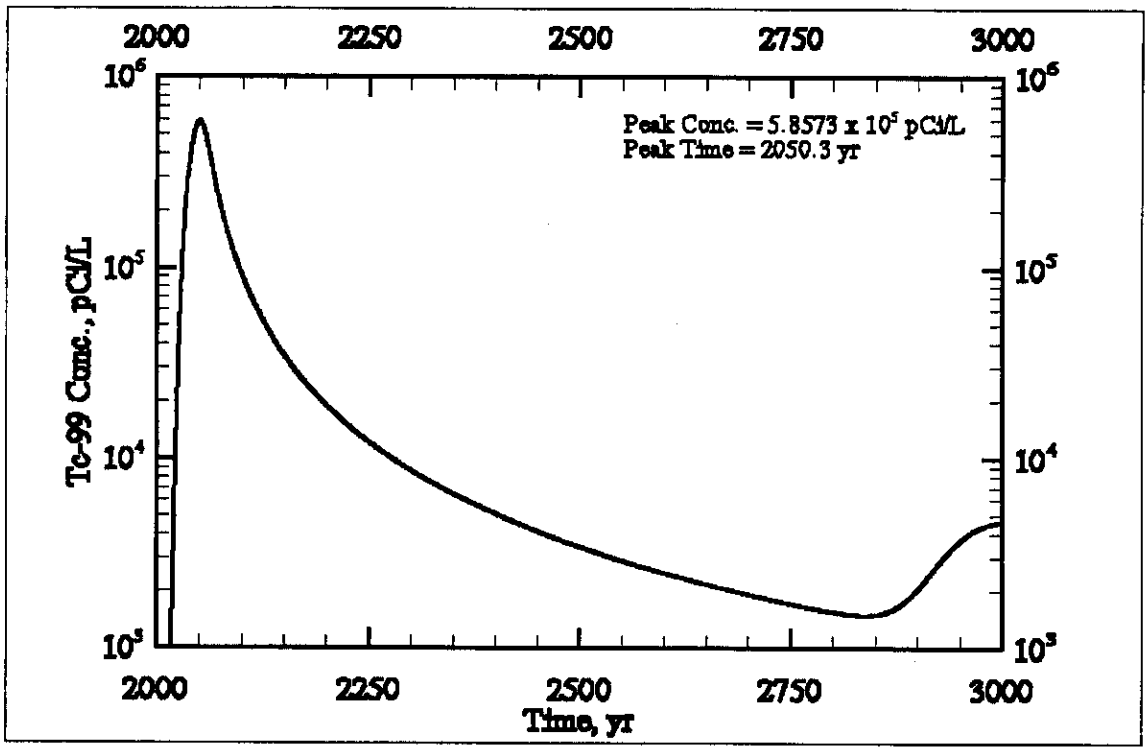


Figure E3.170. Case 12 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

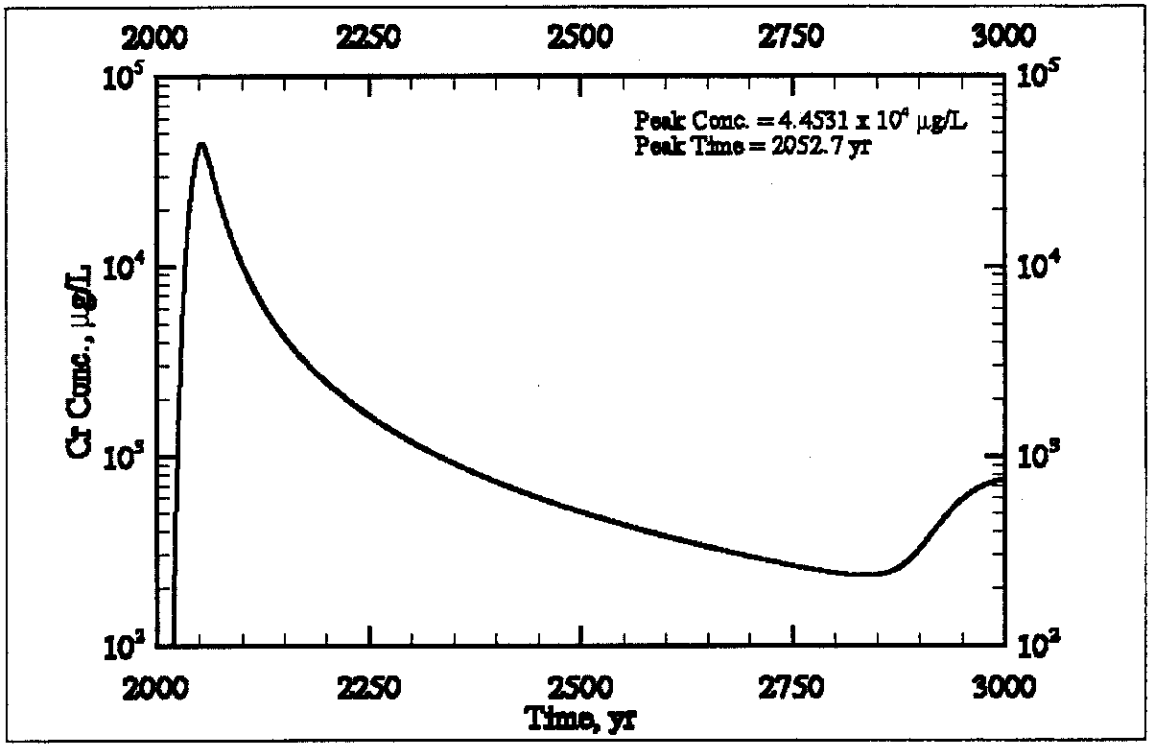


Figure E3.171. Case 12 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

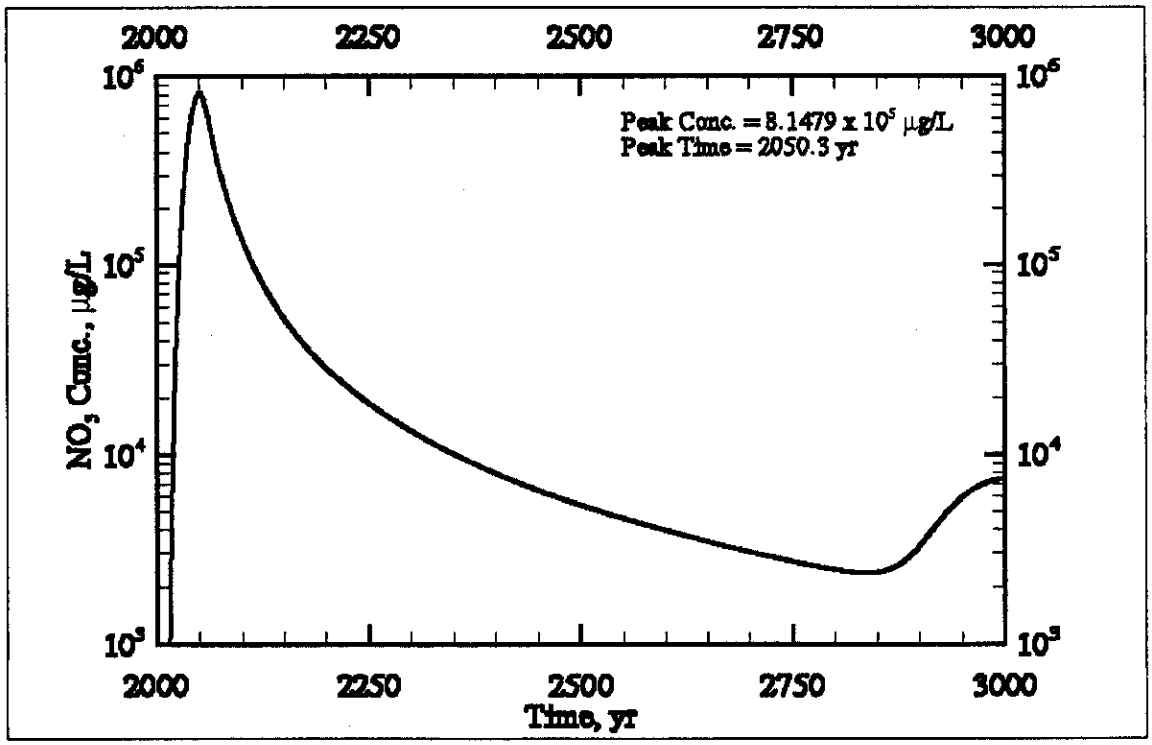


Figure E3.172. Case 12 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

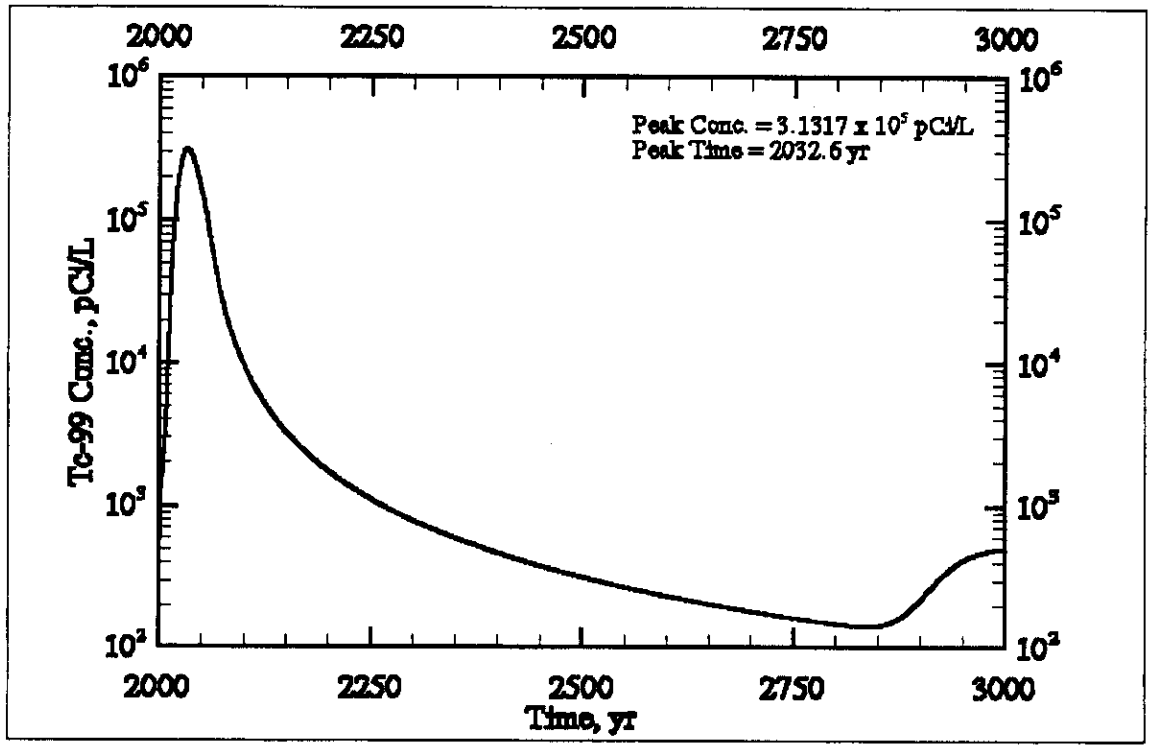


Figure E3.173. Case 12 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

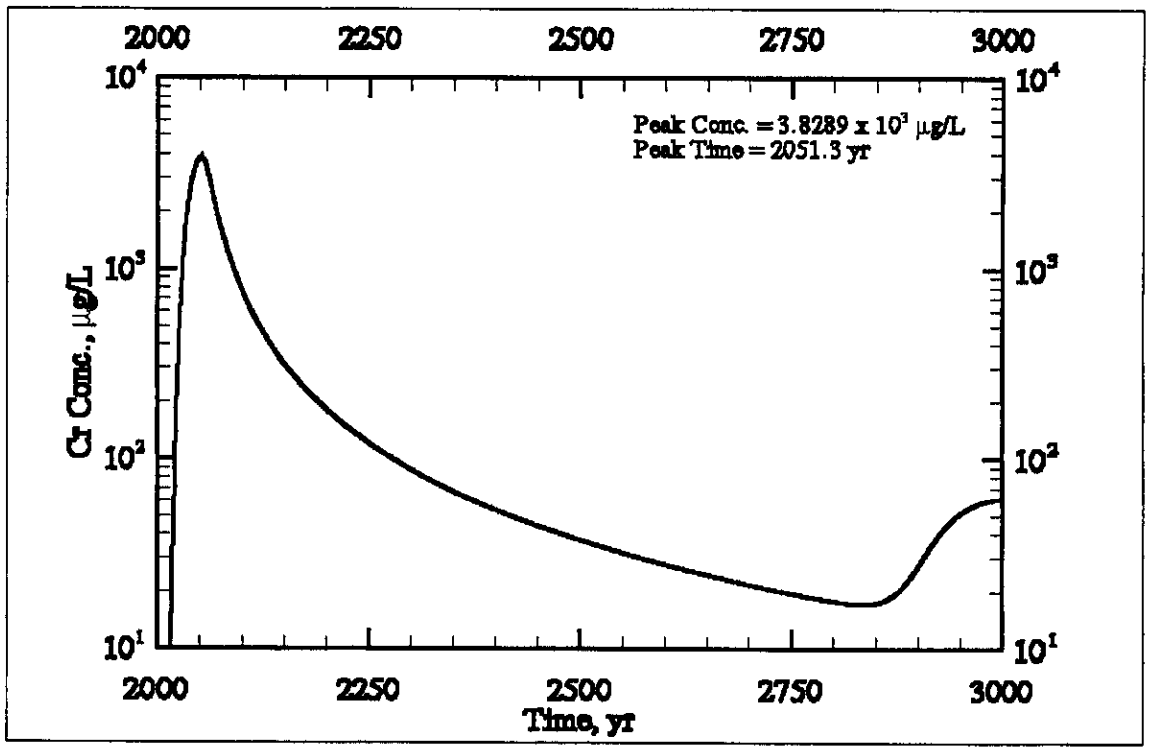


Figure E3.174. Case 12 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

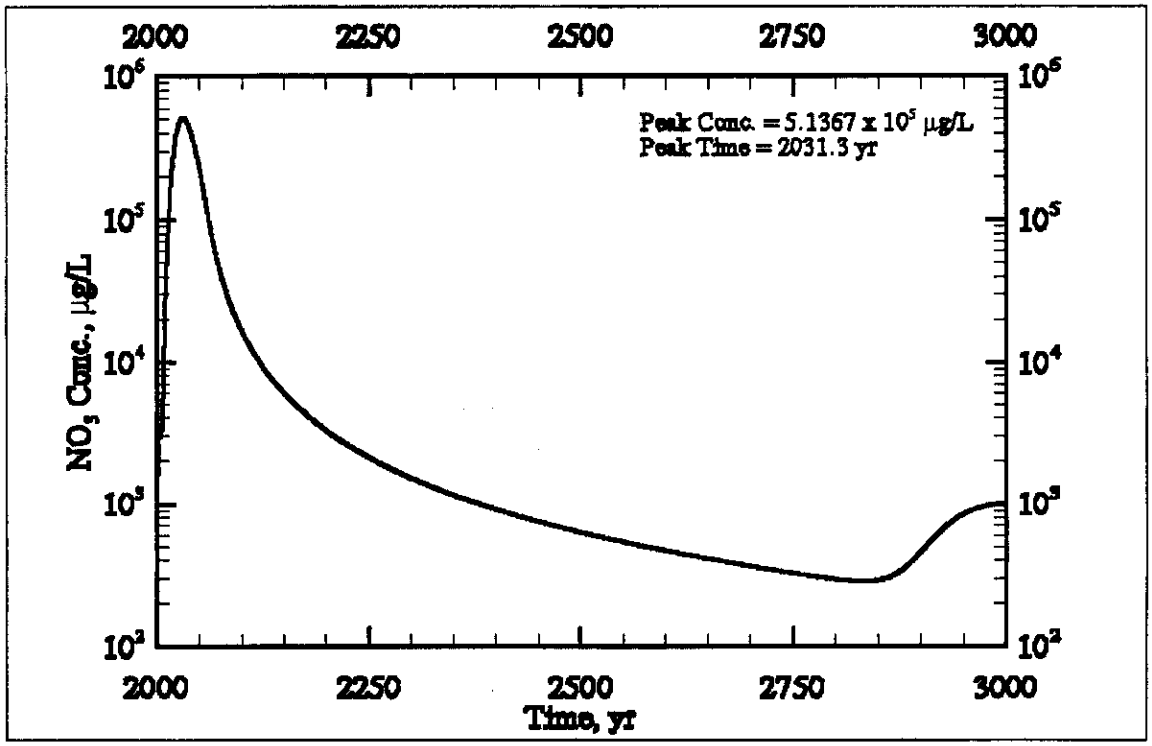


Figure E3.175. Case 12 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

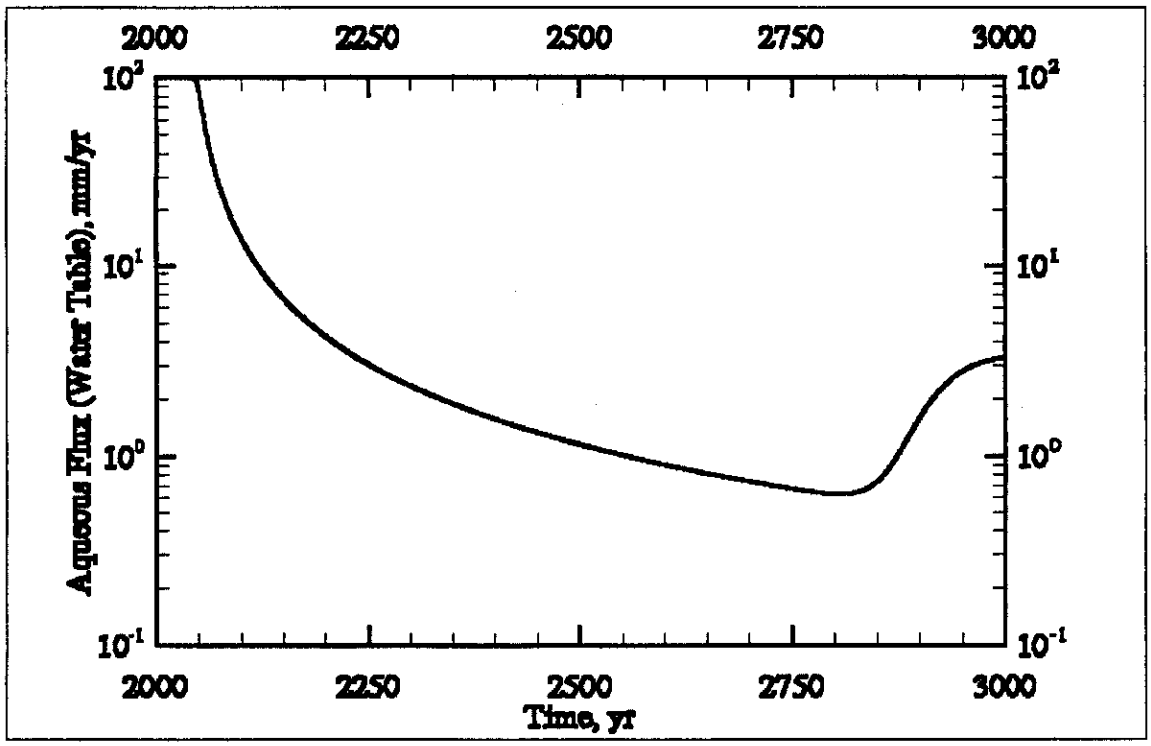


Figure E3.176. Case 12 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

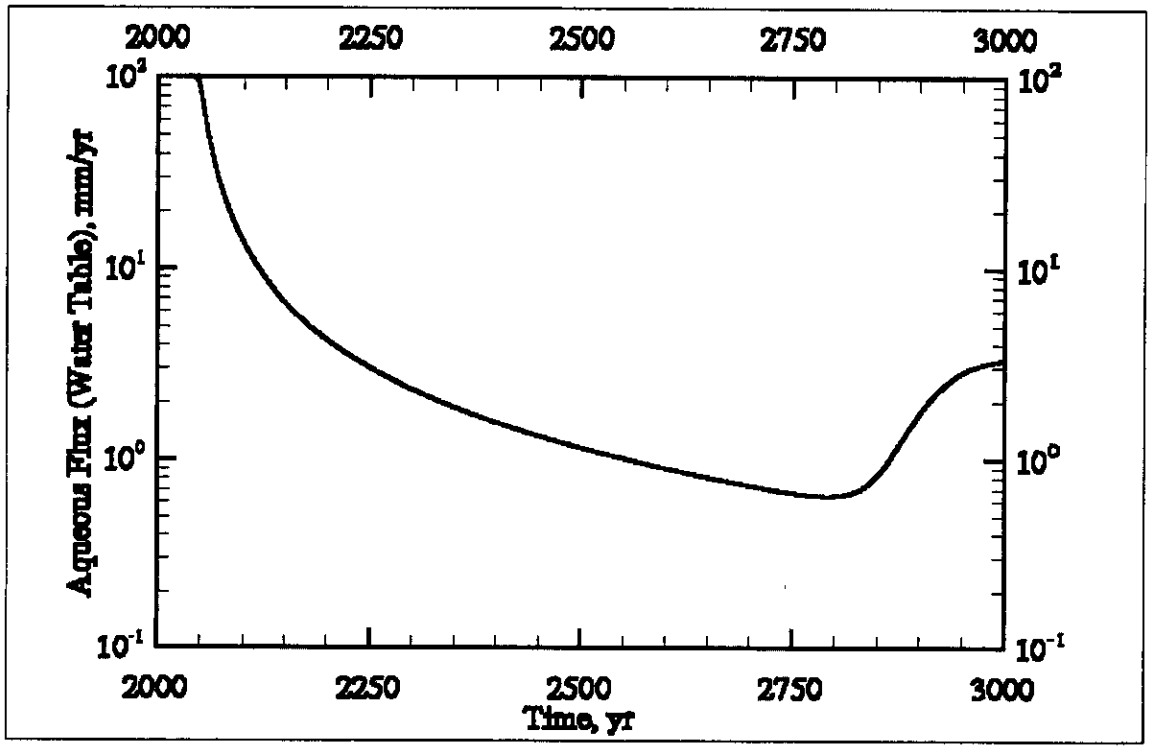


Figure E3.177. Case 12 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

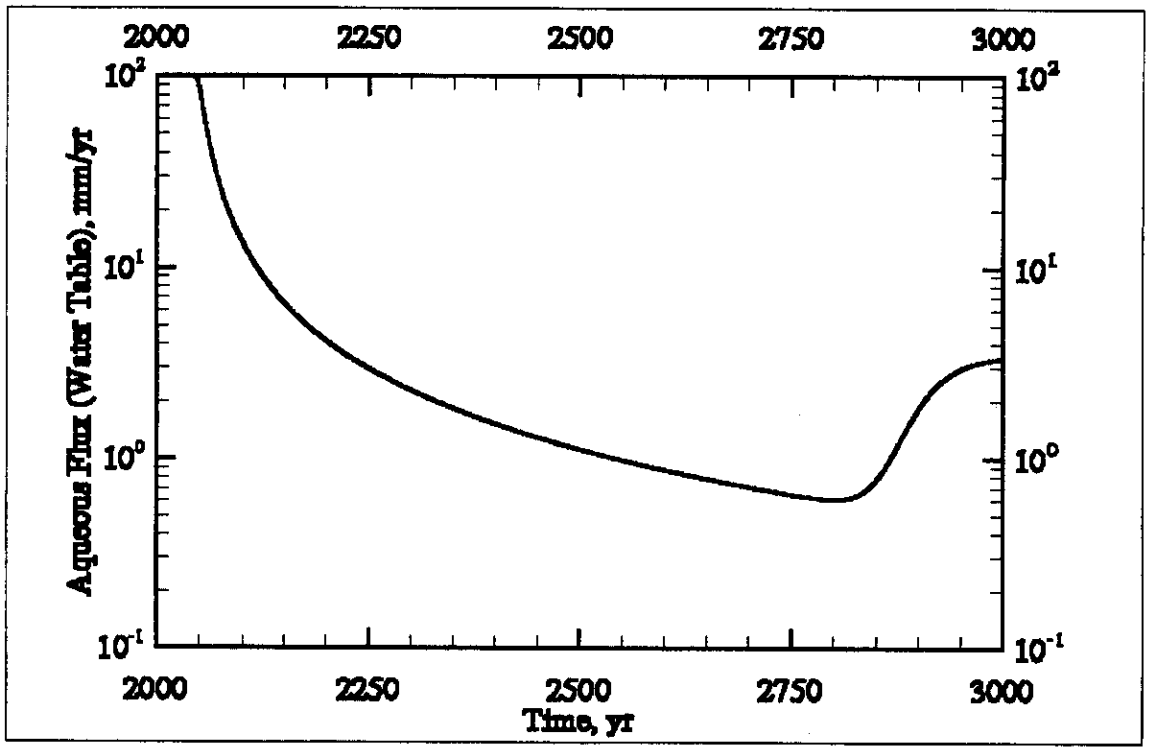


Figure E3.178. Case 12 Area-Weighted Average Tc-99 Concentration versus Time at the Compliance Points

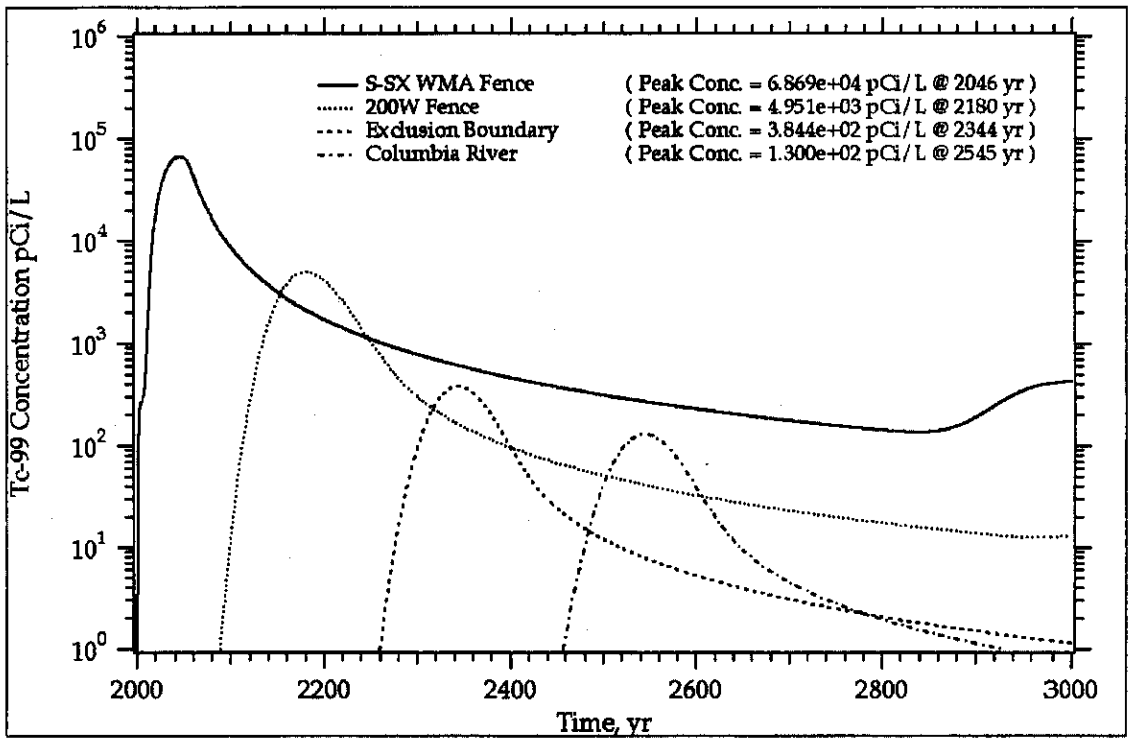


Figure E3.179. Case 12 Area-Weighted Average Cr Concentration versus Time at the Compliance Points

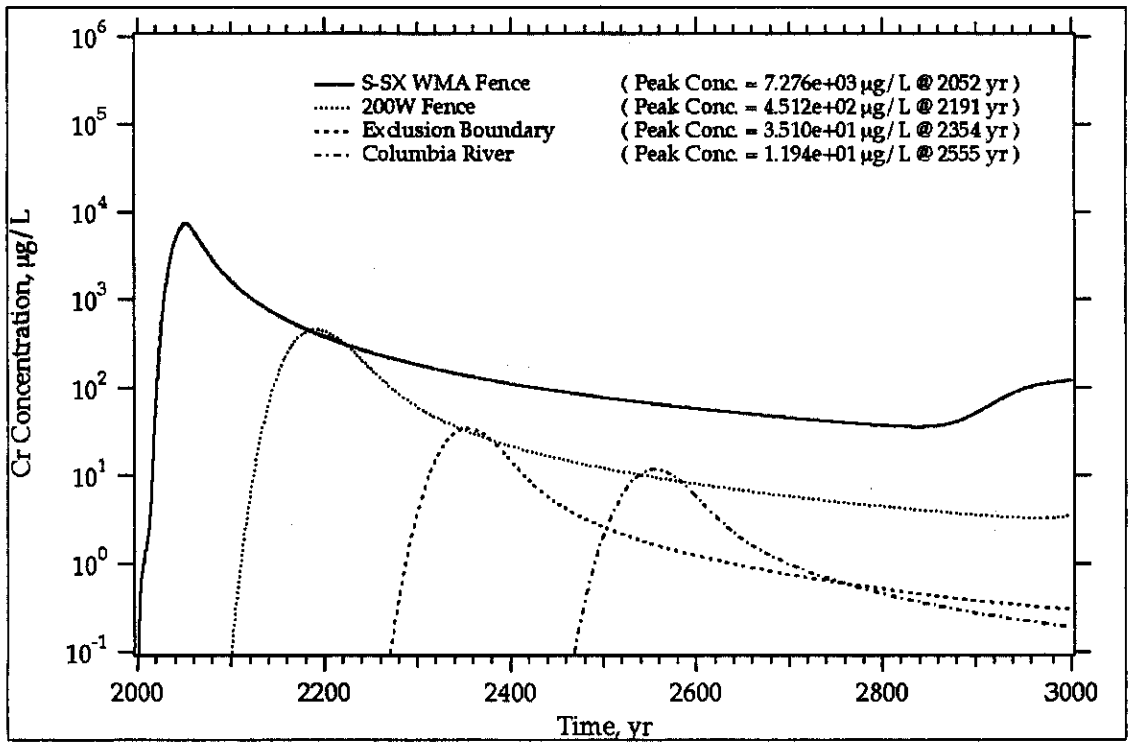
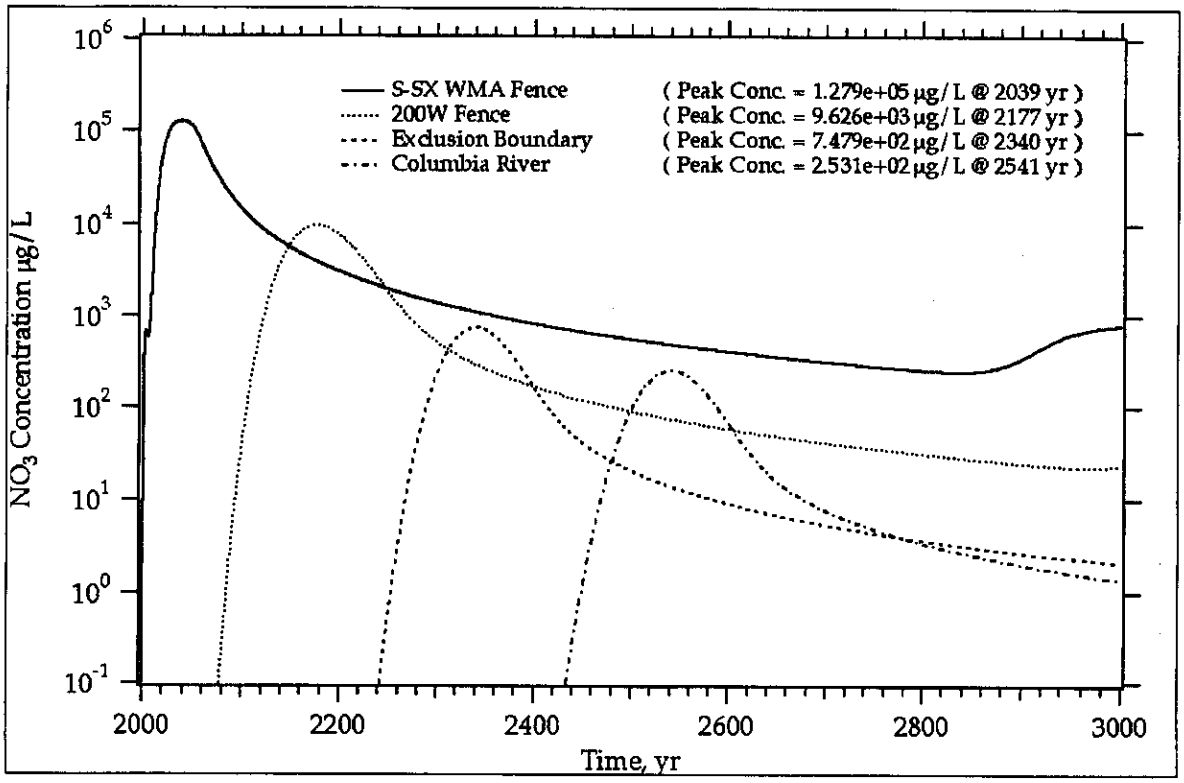


Figure E3.180. Case 12 Area-Weighted Average NO_3 Concentration versus Time at the Compliance Points



E3.13.0 CASE 13: NO BARRIER AND WATER-LINE LEAK (200,000 GAL IN 5 DAYS)

This scenario involves simulating flow and transport for cross-sections through tanks (a) SX-107, -108, and -109; (b) SX-113, -114, and -115; and (c) S-104, -105, and -106 considering natural infiltration, water-line leak (200,000 gal in 5 days) for tank SX-115 only, and no barrier until closure in 2040.

Figure E3.181. Case 13 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

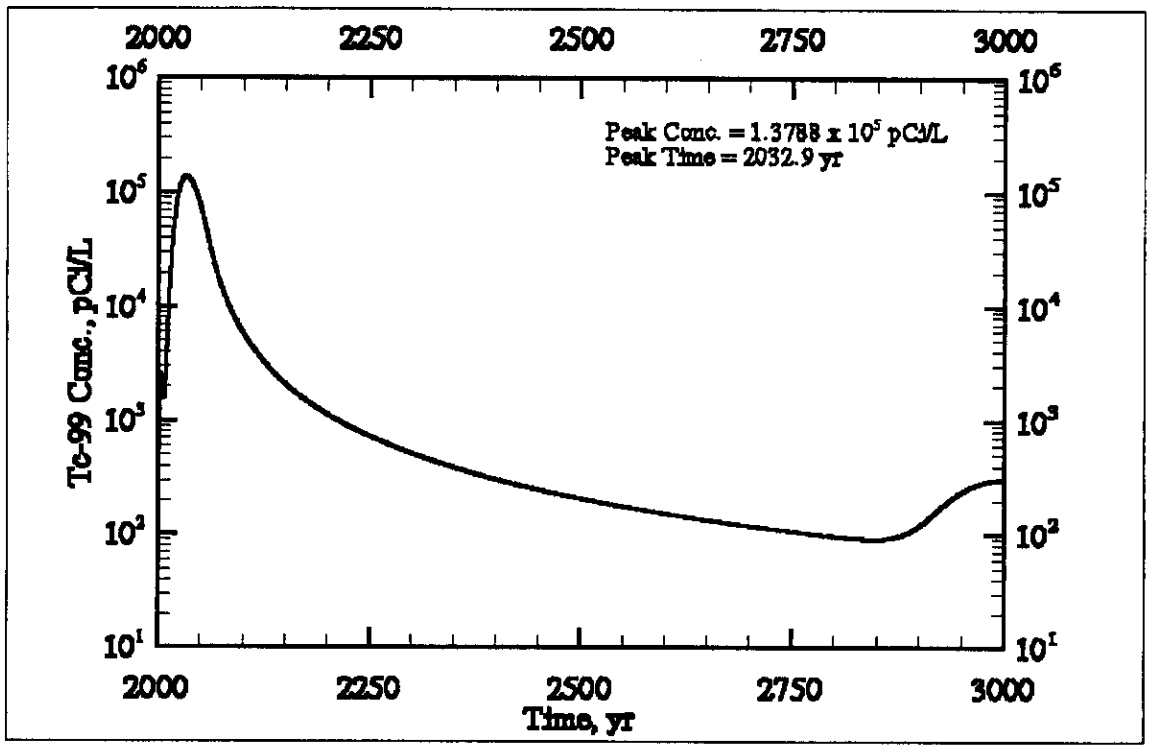


Figure E3.182. Case 13 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

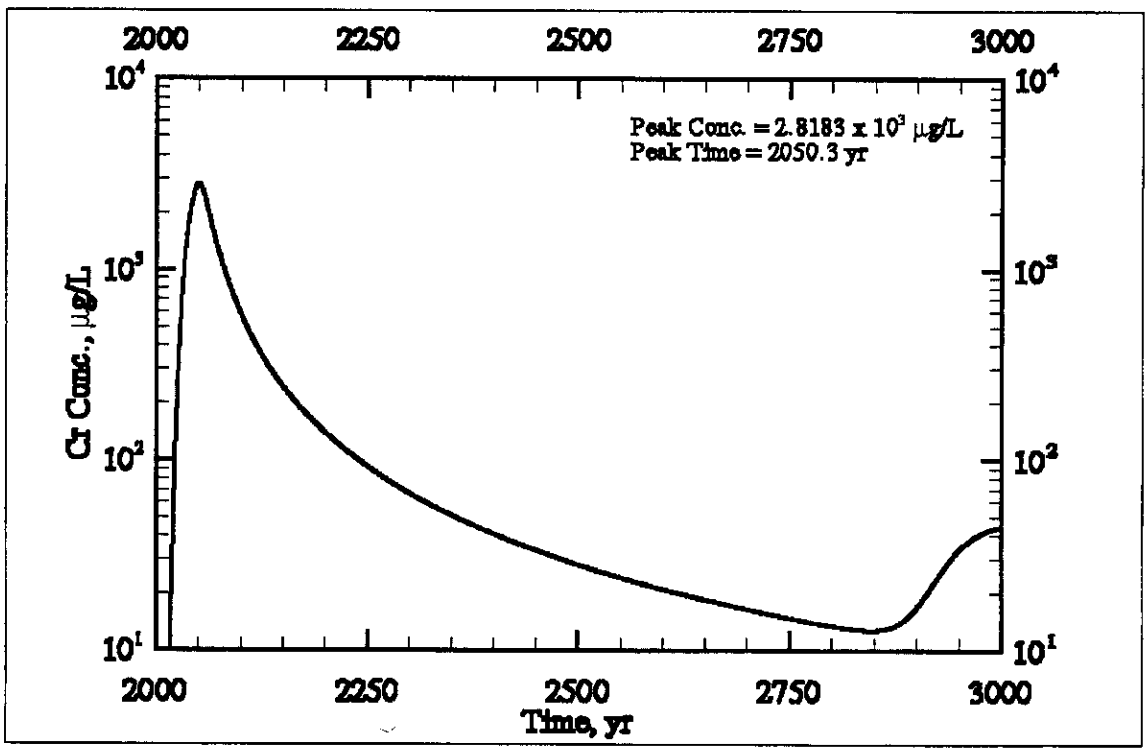


Figure E3.183. Case 13 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

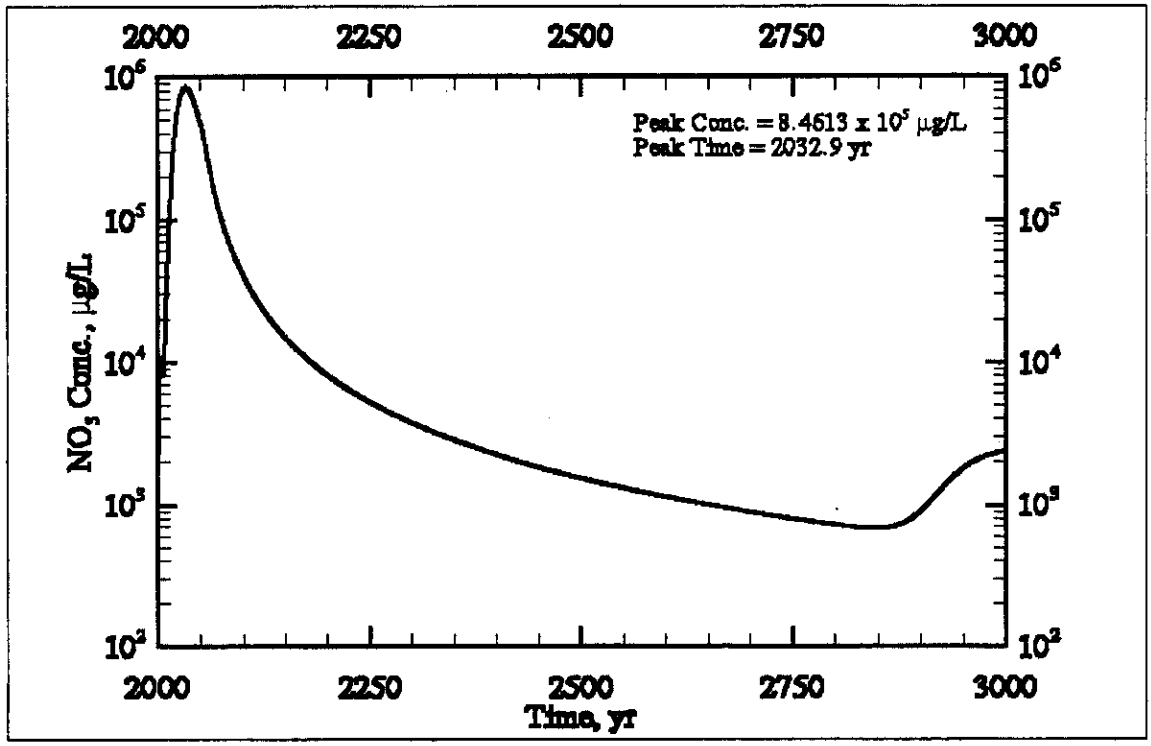


Figure E3.184. Case 13 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

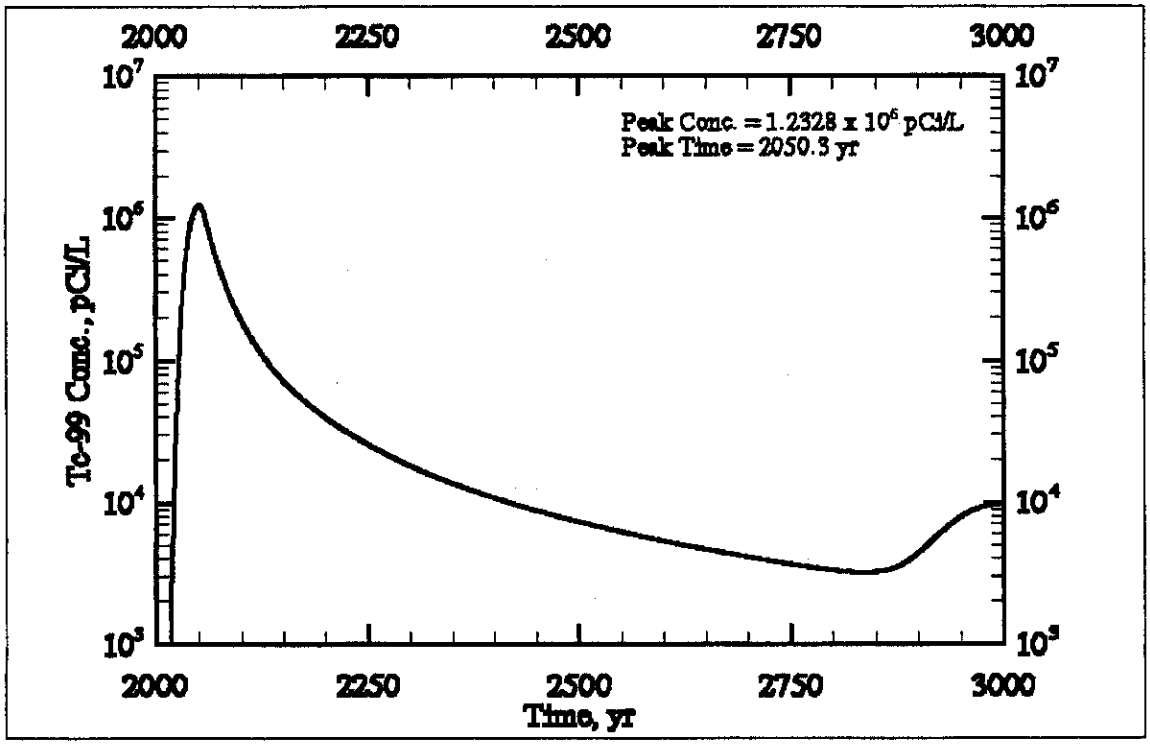


Figure E3.185. Case 13 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

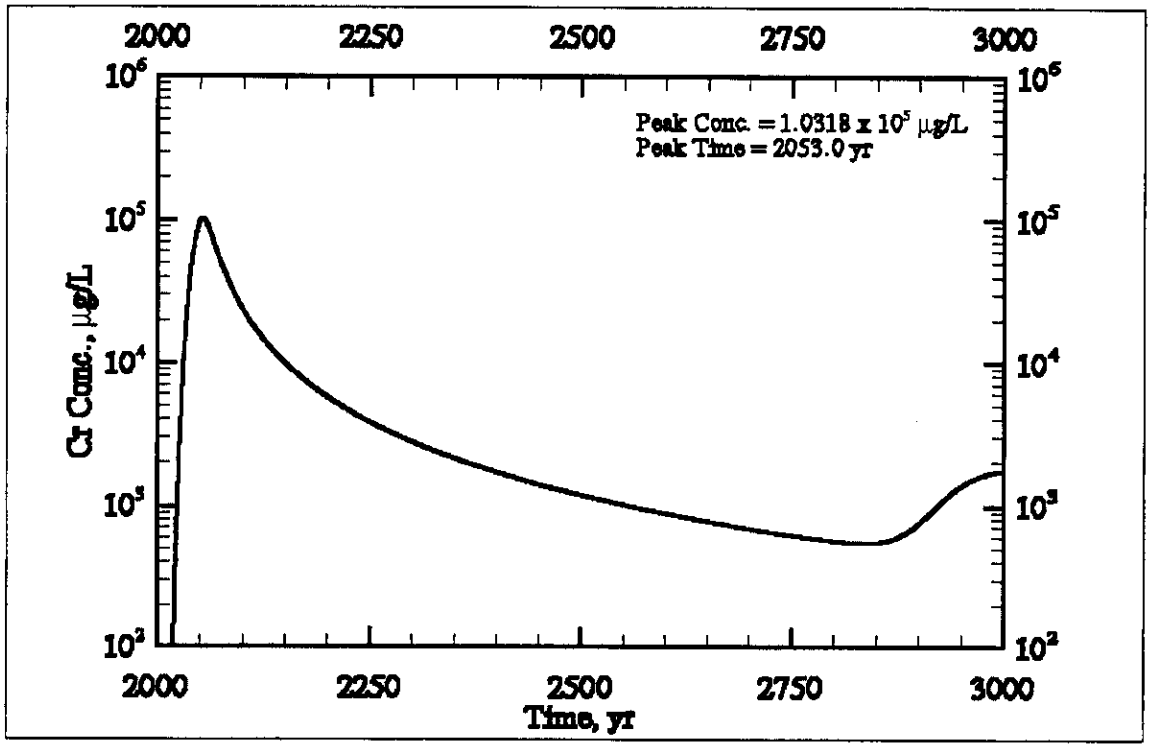


Figure E3.186. Case 13 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

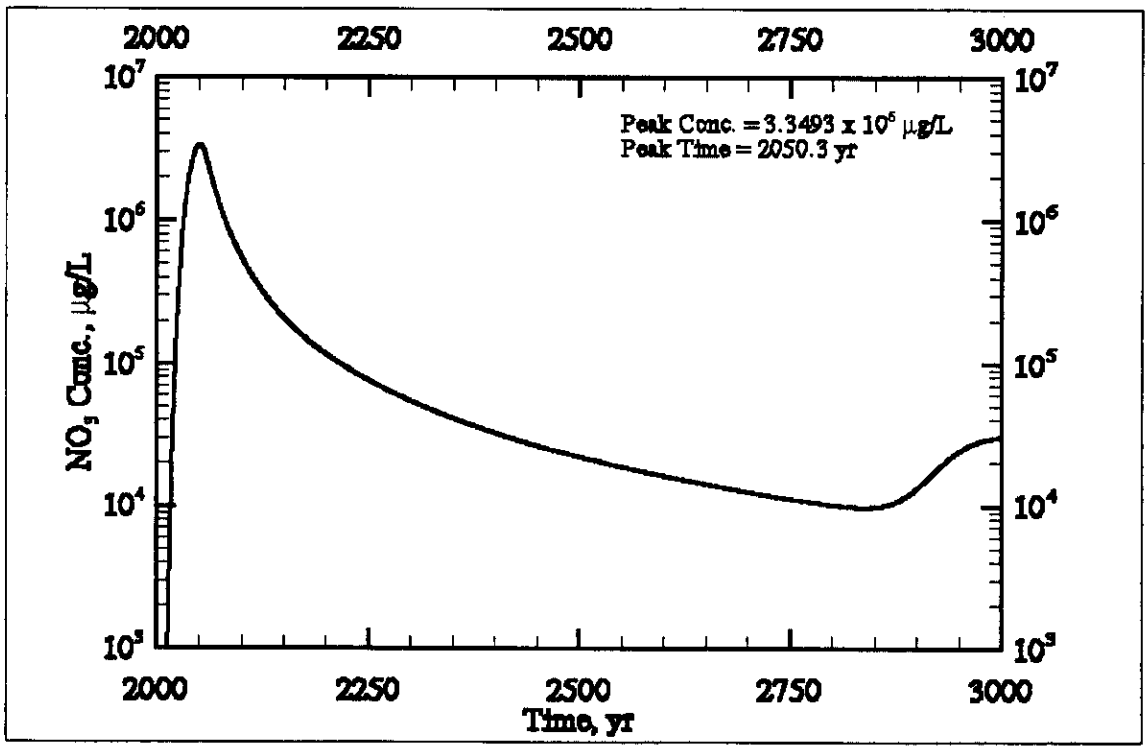


Figure E3.187. Case 13 Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

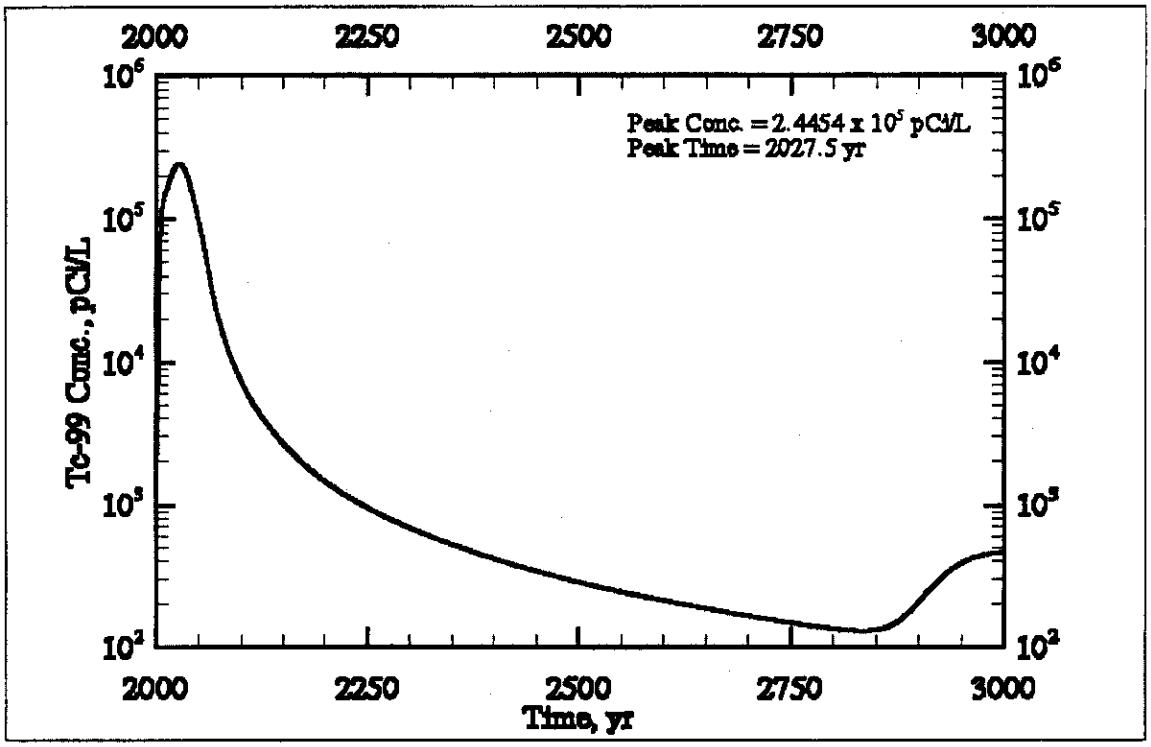


Figure E3.188. Case 13 Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

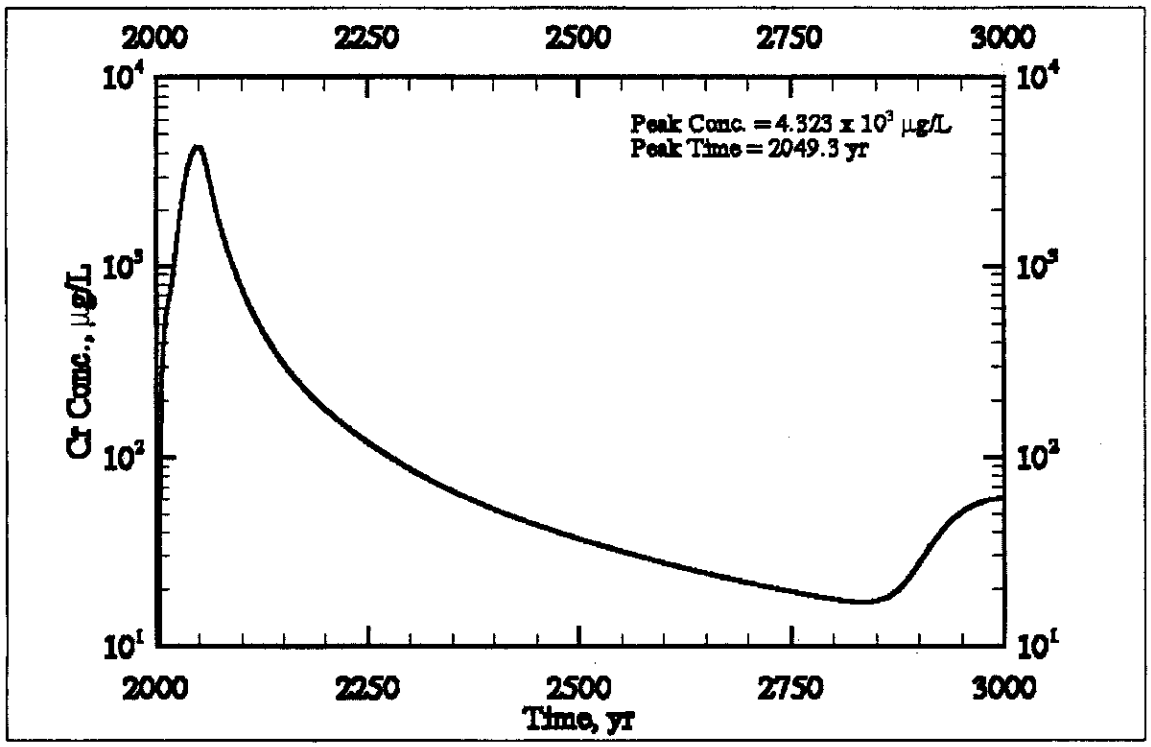


Figure E3.189. Case 13 NO_3 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

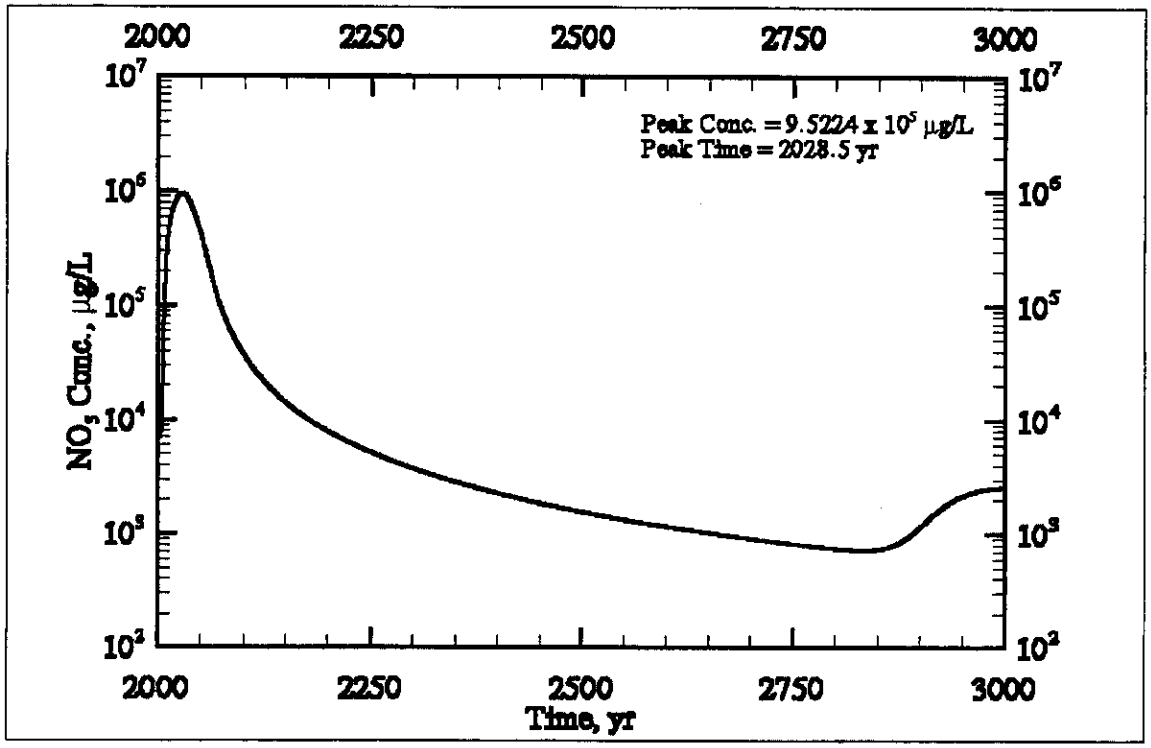


Figure E3.190. Case 13 Aqueous Flux versus Time at the Water Table for Cross-Section S-CC' (S-104, -105, -106)

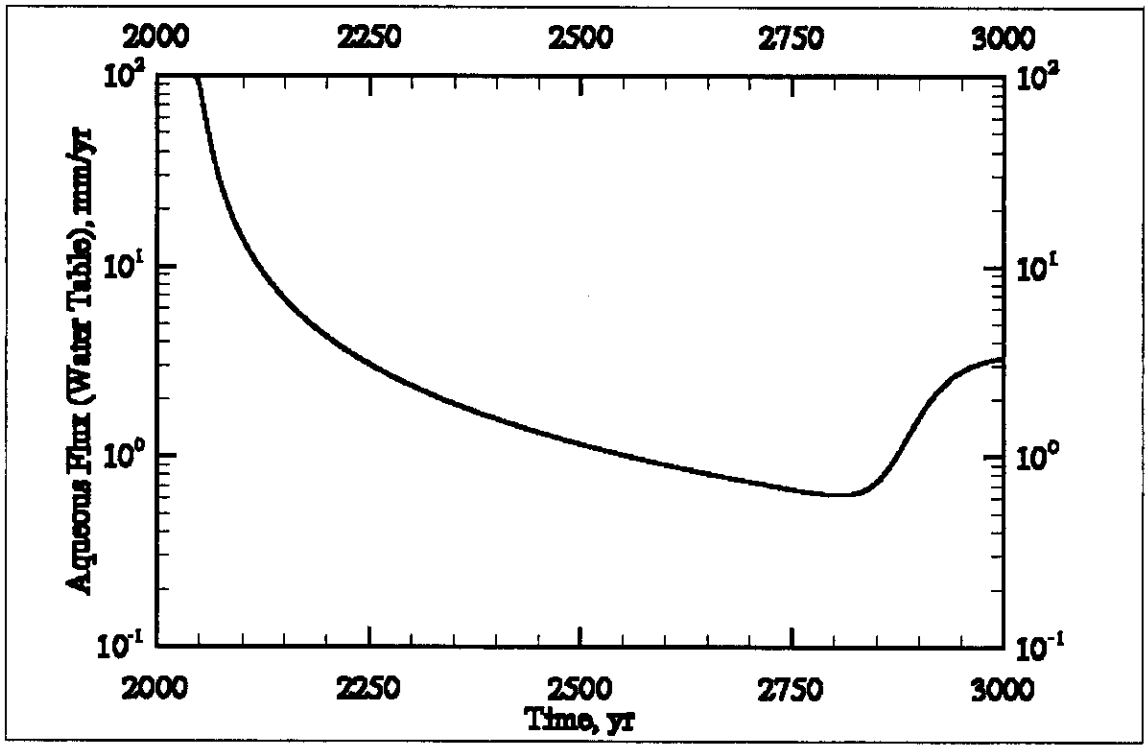


Figure E3.191. Case 13 Aqueous Flux versus Time at the Water Table for Cross-Section SX-DD' (SX-107, -108, -109)

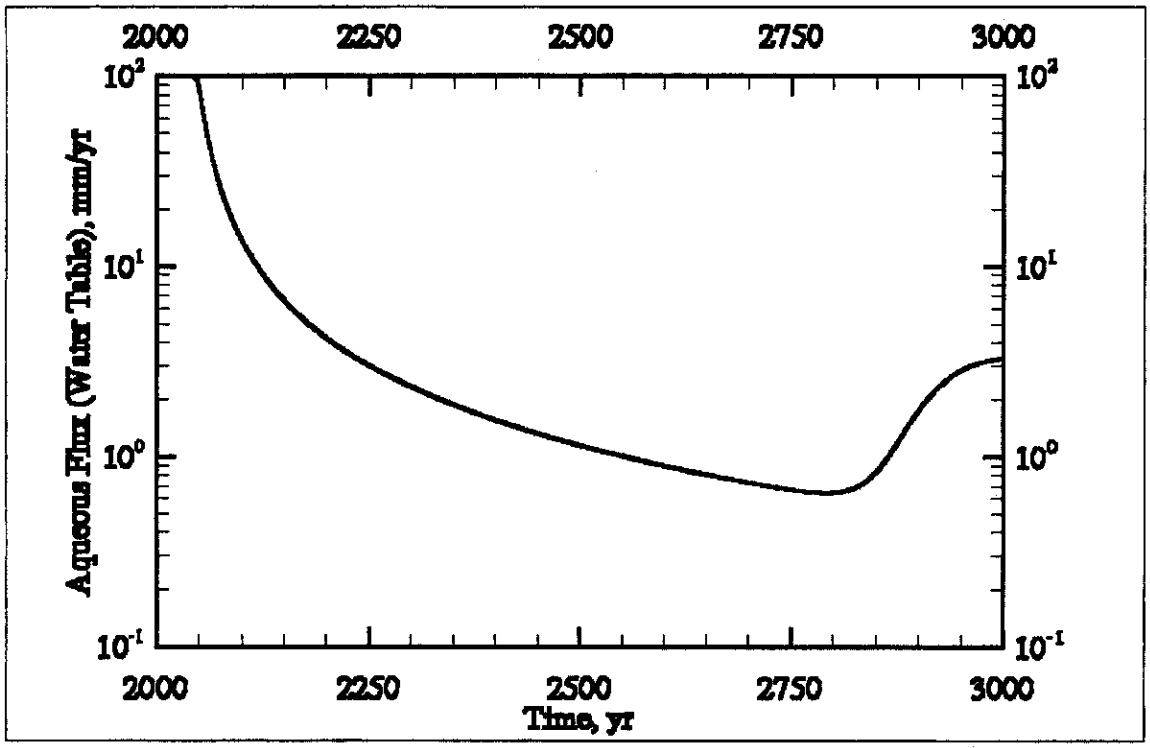


Figure E3.192. Case 13 Aqueous Flux versus Time at the Water Table for Cross-Section SX-FF' (SX-113, -114, -115)

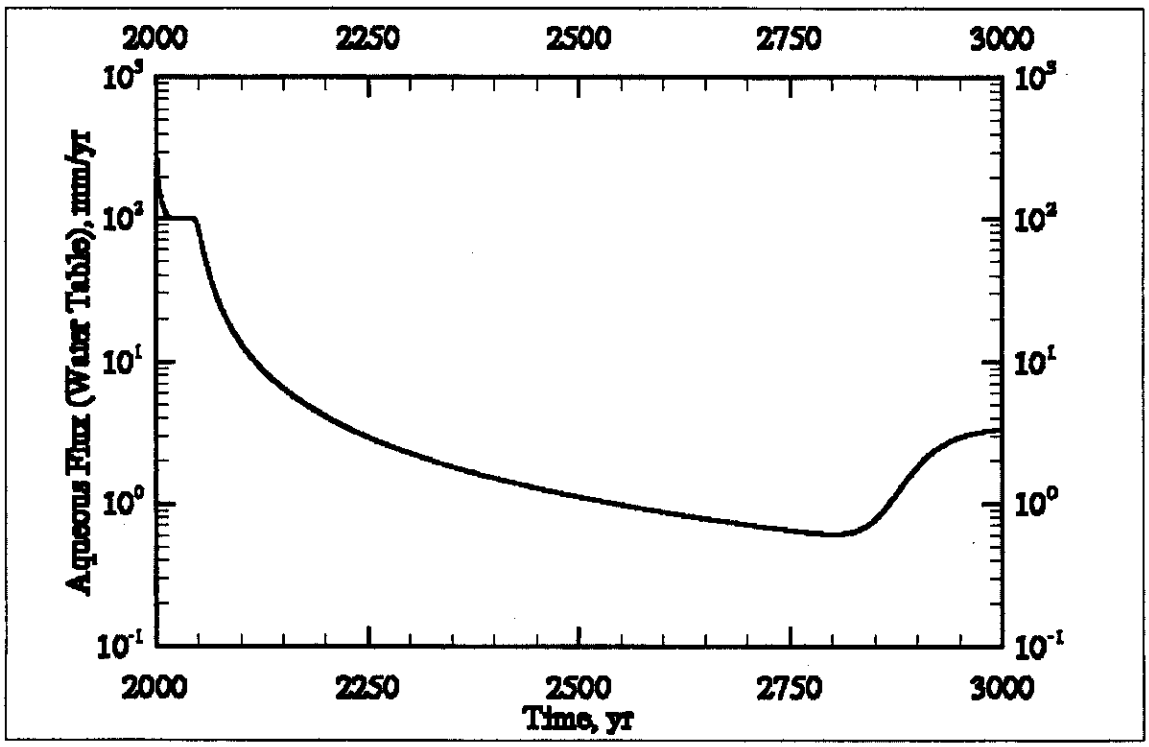


Figure E3.193. Case 13 Area-Weighted Average Tc-99 Concentration and Dose versus Time at Compliance Points

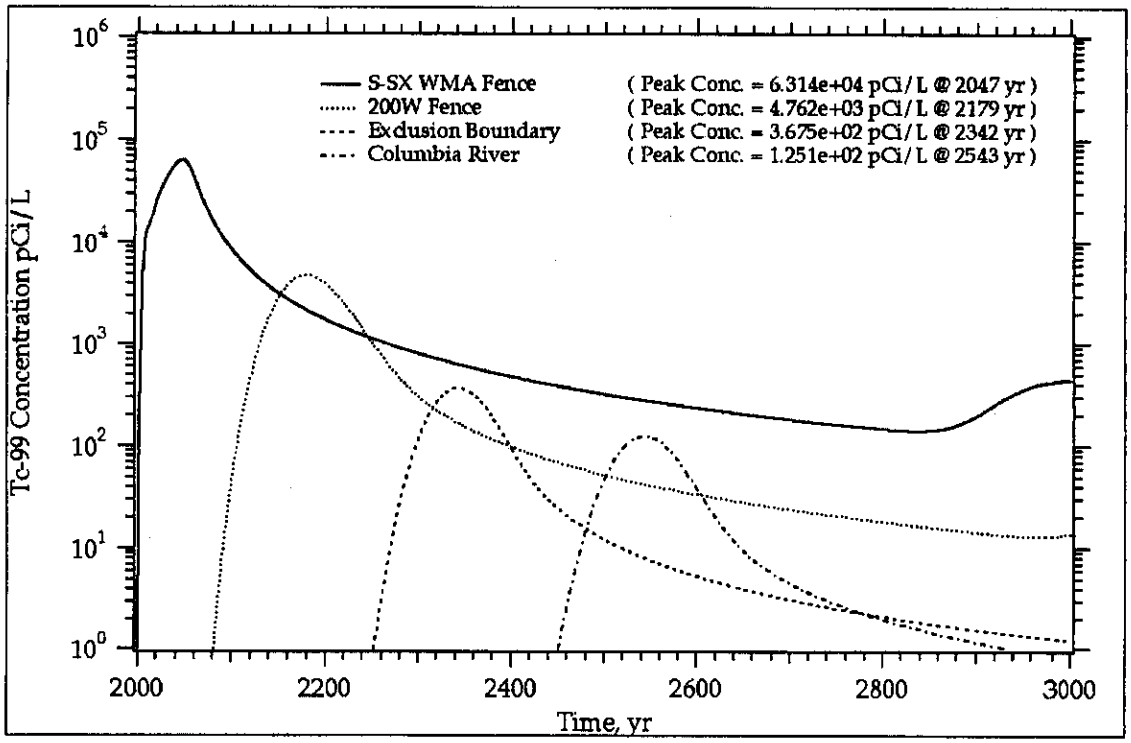


Figure E3.194. Case 13 Area-Weighted Average Cr Concentration versus Time at Compliance Points

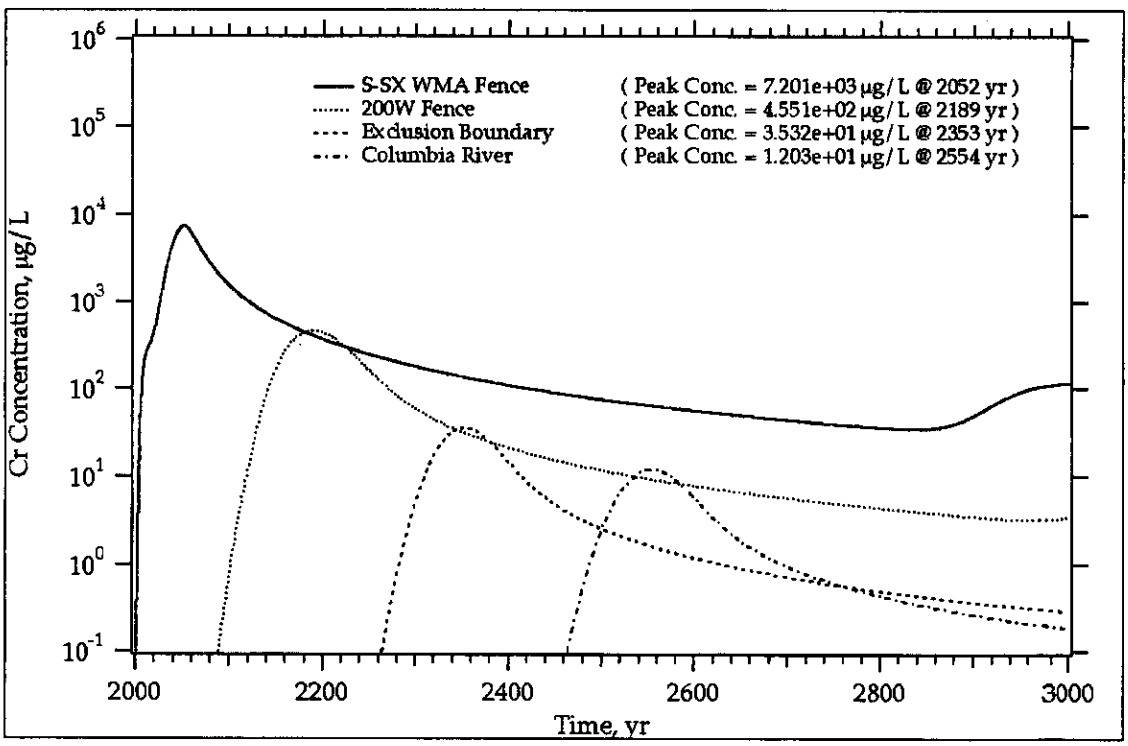
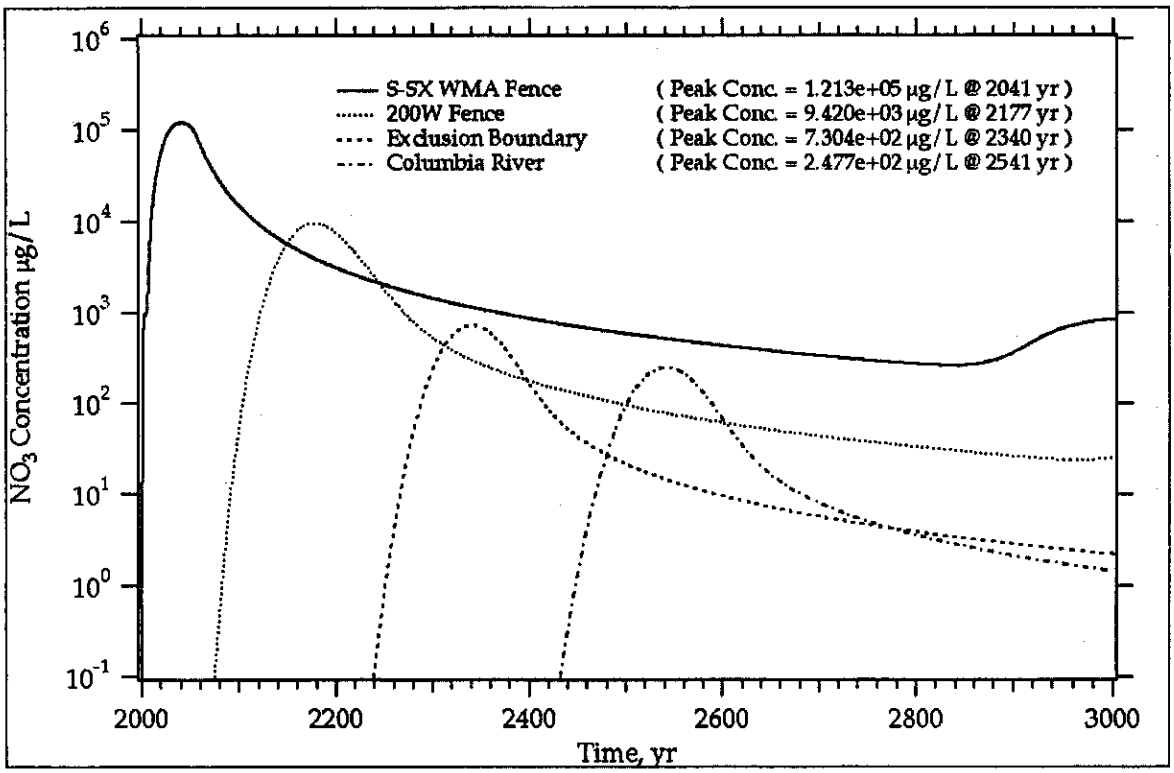


Figure E3.195. Case 13 Area-Weighted Average NO_3 Concentration versus Time at Compliance Points



E3.14.0 CASE 14: THREE-DIMENSIONAL BASE CASE (NO ACTION ALTERNATIVE)

This scenario involves simulating flow and transport for a three-dimensional domain surrounding tank SX-108 considering natural infiltration only, no water-line leak, no interim barrier and a closure barrier by the year 2040. To compare this result against the two-dimensional cross-section through tanks SX-107, -108, and -109, the three-dimensional soil zonation profile was generated by extending the two-dimensional, east-west, cross-section in the north-south direction.

Figure E3.196. Zonations of Three Dimensional Simulation Around Tank SX-108 – View is from the Northwest

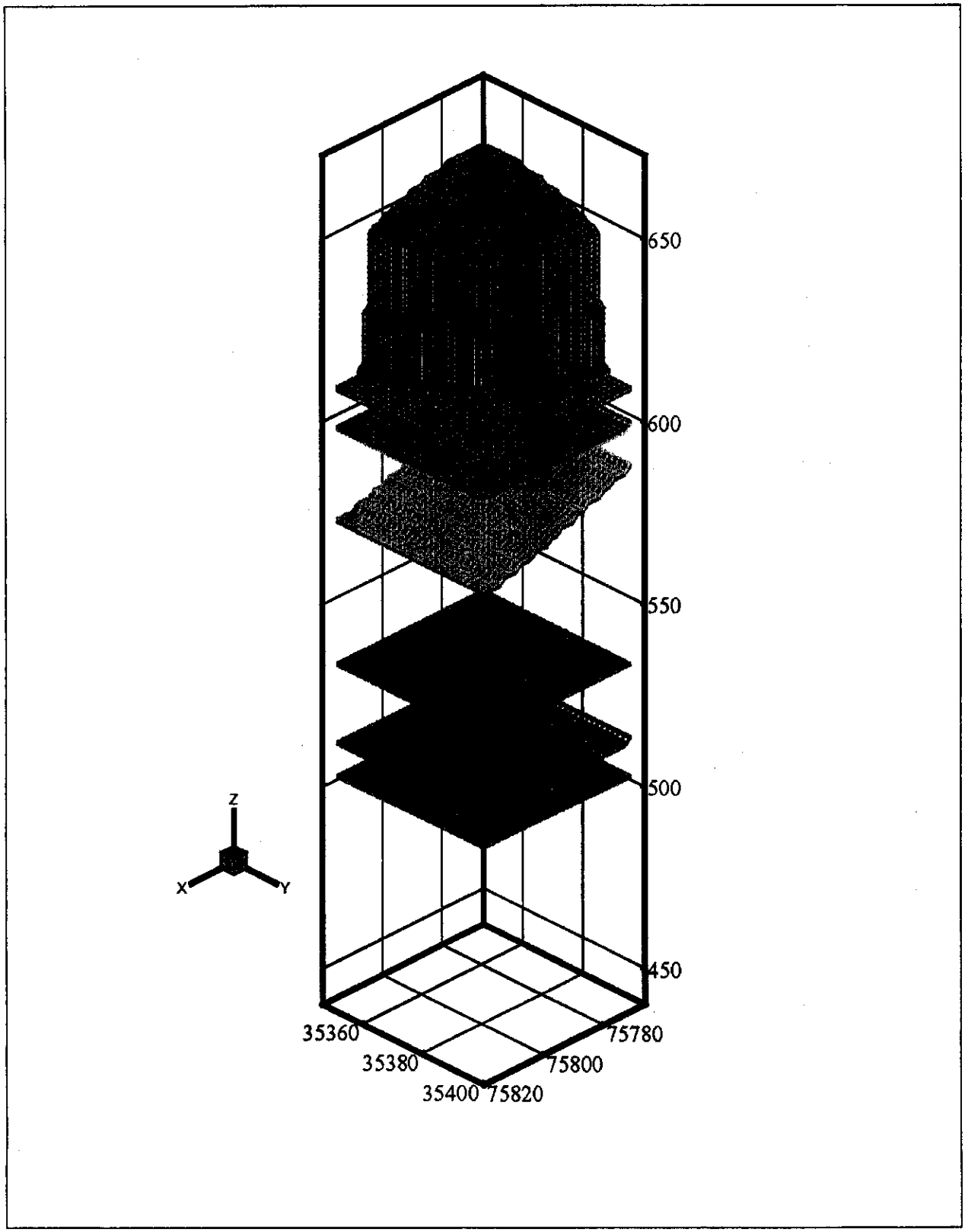


Figure E3.197. Zonations (a) and Tc-99 (pCi/L) Initial Conditions (b) for the Three-Dimensional Simulation around Tank SX-108

These figures show the values along the front plane (y-direction). The geology and the initial inventory are replicated for all the y-planes. The dome-shaped geometry of the tank is represented in the y-direction.

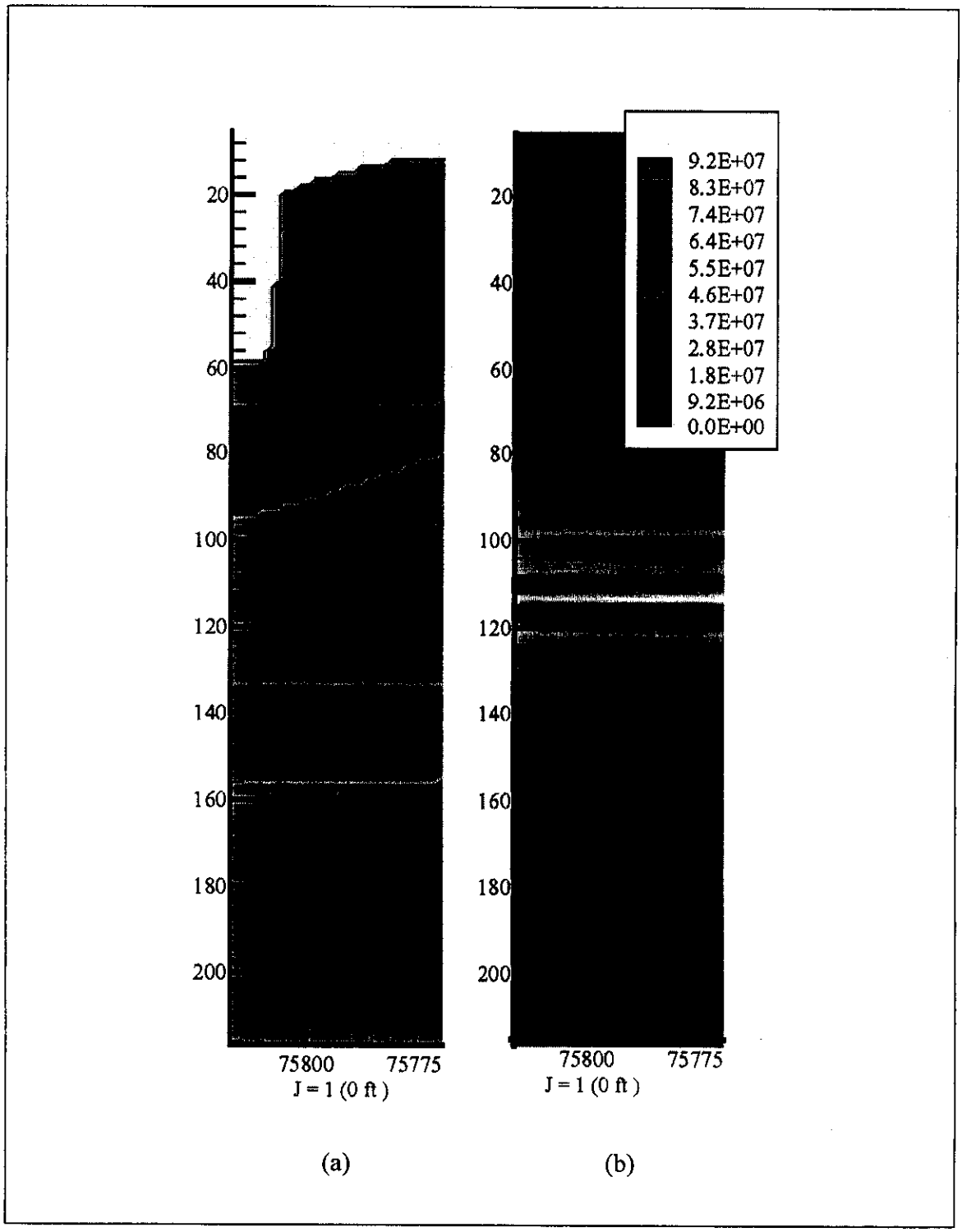


Figure E3.198. SX-108 Three-Dimensional Simulation Results of Aqueous Volumetric Water Flux Vectors in the X-Z Direction for Three Different Y Planes (front, middle, and back) for Year 2000 (100 mm/year recharge). Vectors are Scaled for Magnitude (see legend).

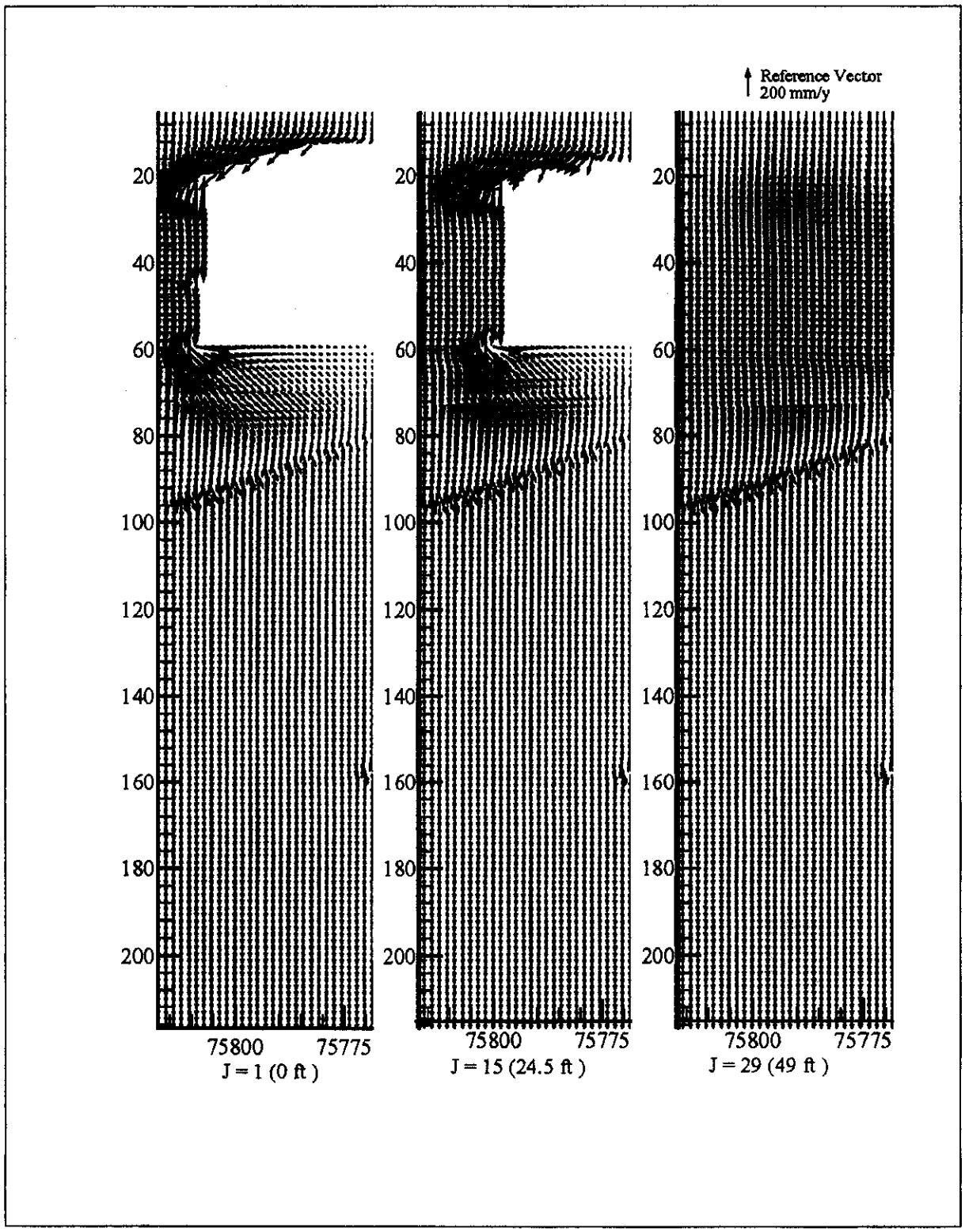


Figure E3.199. Tank SX-108 Three-Dimensional Simulation Results of Aqueous Volumetric Water Flux Vectors in the X-Y Direction for Two Different X Planes Near the Top of Tank SX-108 for the Year 2000 (100 mm/year recharge). Vectors are Scaled for Magnitude (see legend).

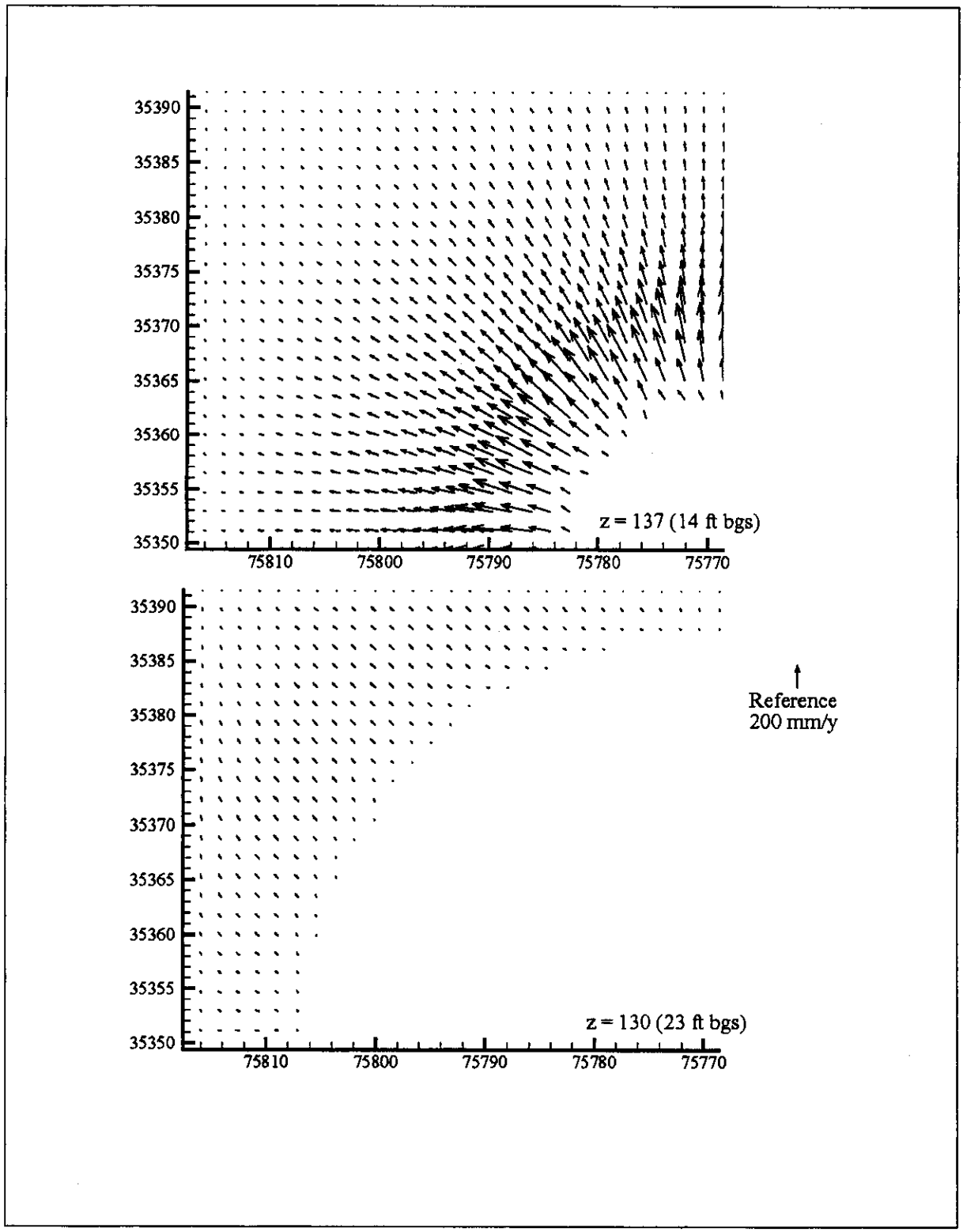


Figure E3.200. Tank SX-108 Three-Dimensional Simulation Results of Aqueous Volumetric Water Flux Vectors in the X-Y Direction for Two Different X Planes Near the Bottom of Tank SX-108 for Year 2000 (100 mm/year recharge). Vectors are Scaled for Magnitude (see legend).

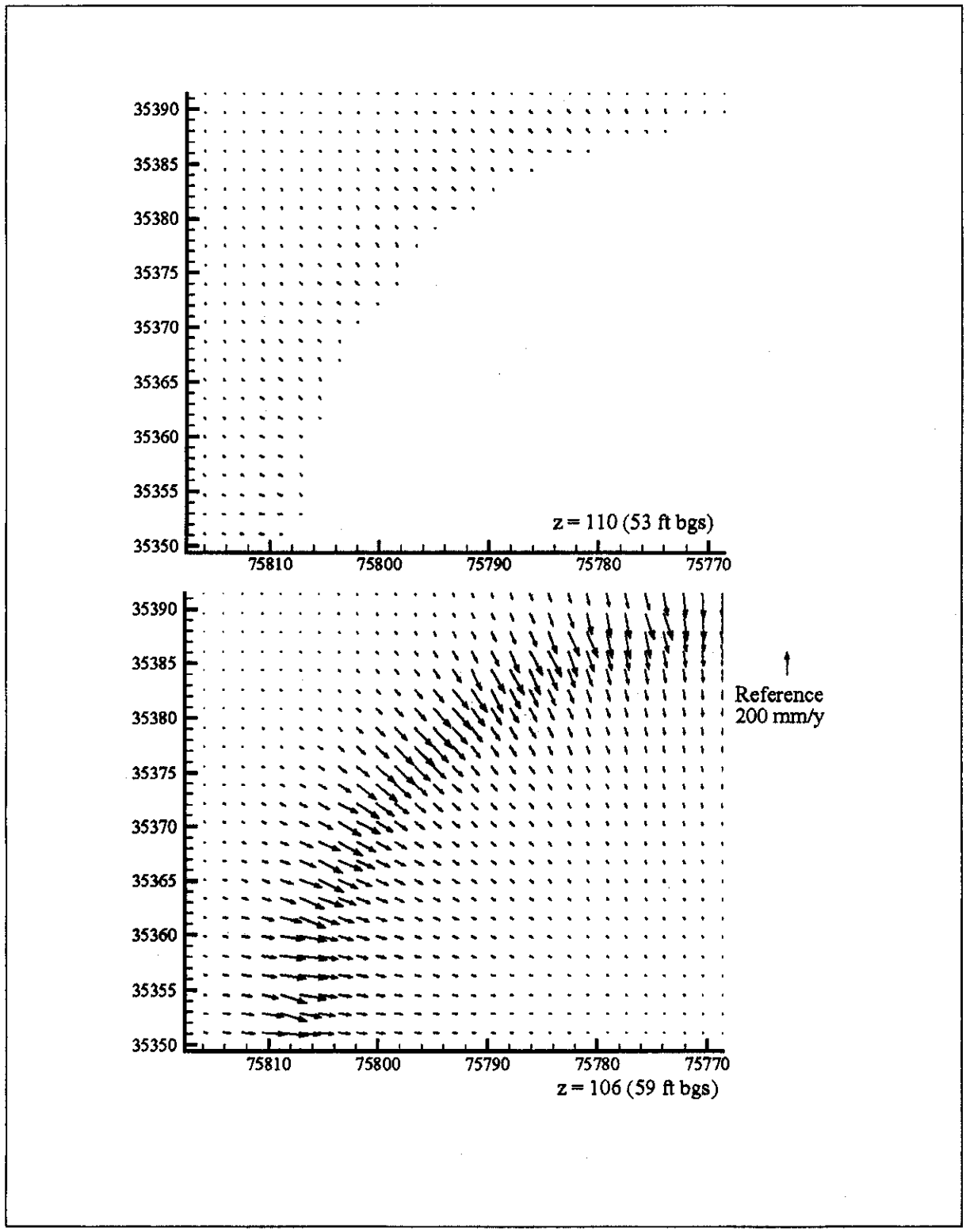


Figure E3.201. Tank SX-108 Three-Dimensional Simulation Results of Aqueous Saturation in the Three Different Y Planes (front, middle, and back) for Year 2000 (100 mm/year recharge)

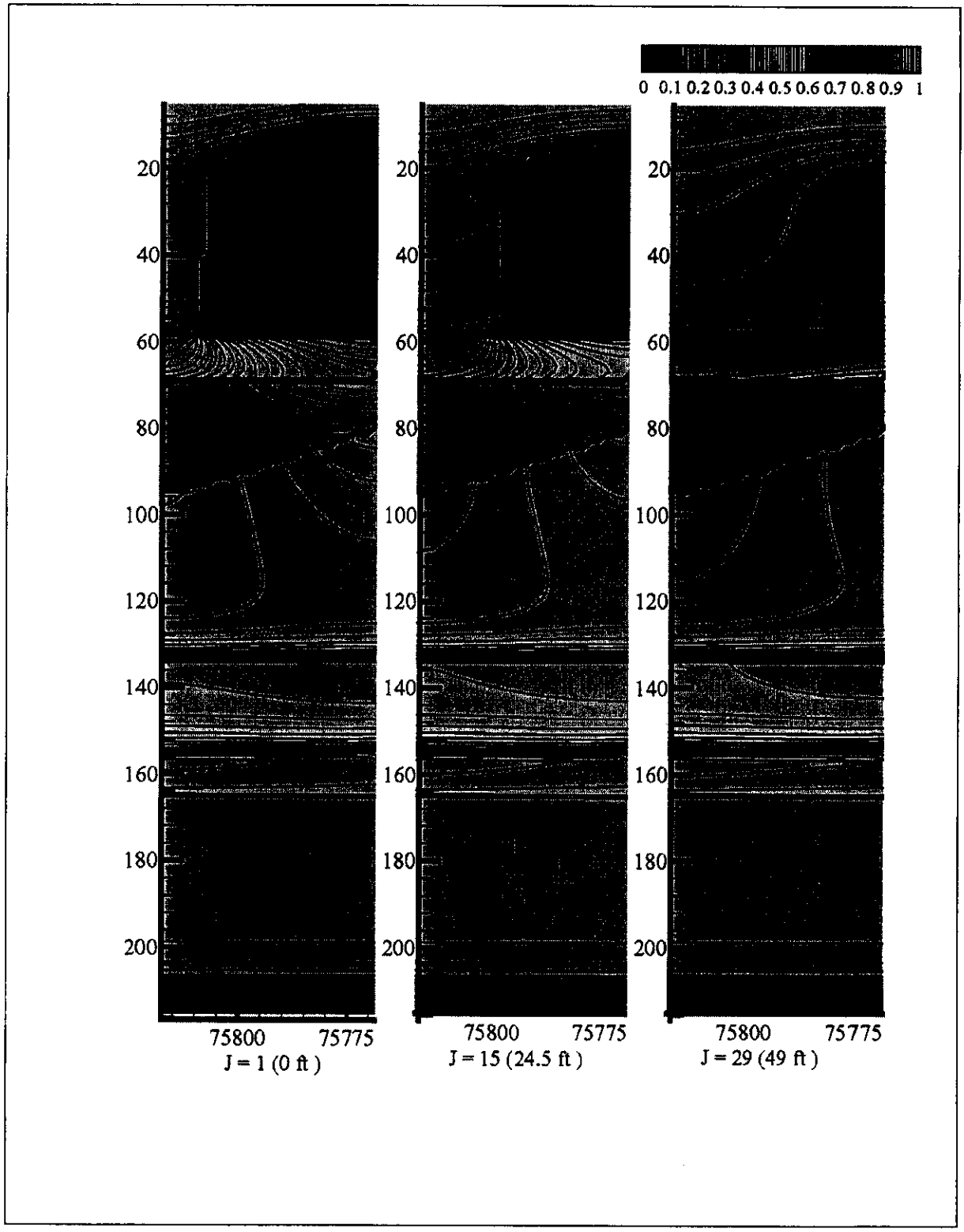


Figure E3.202. SX-108 Three-Dimensional Simulation Results of Tc-99 Concentrations (pCi/L) for Three Different Y Planes (front, middle, and back) for the Year 2040

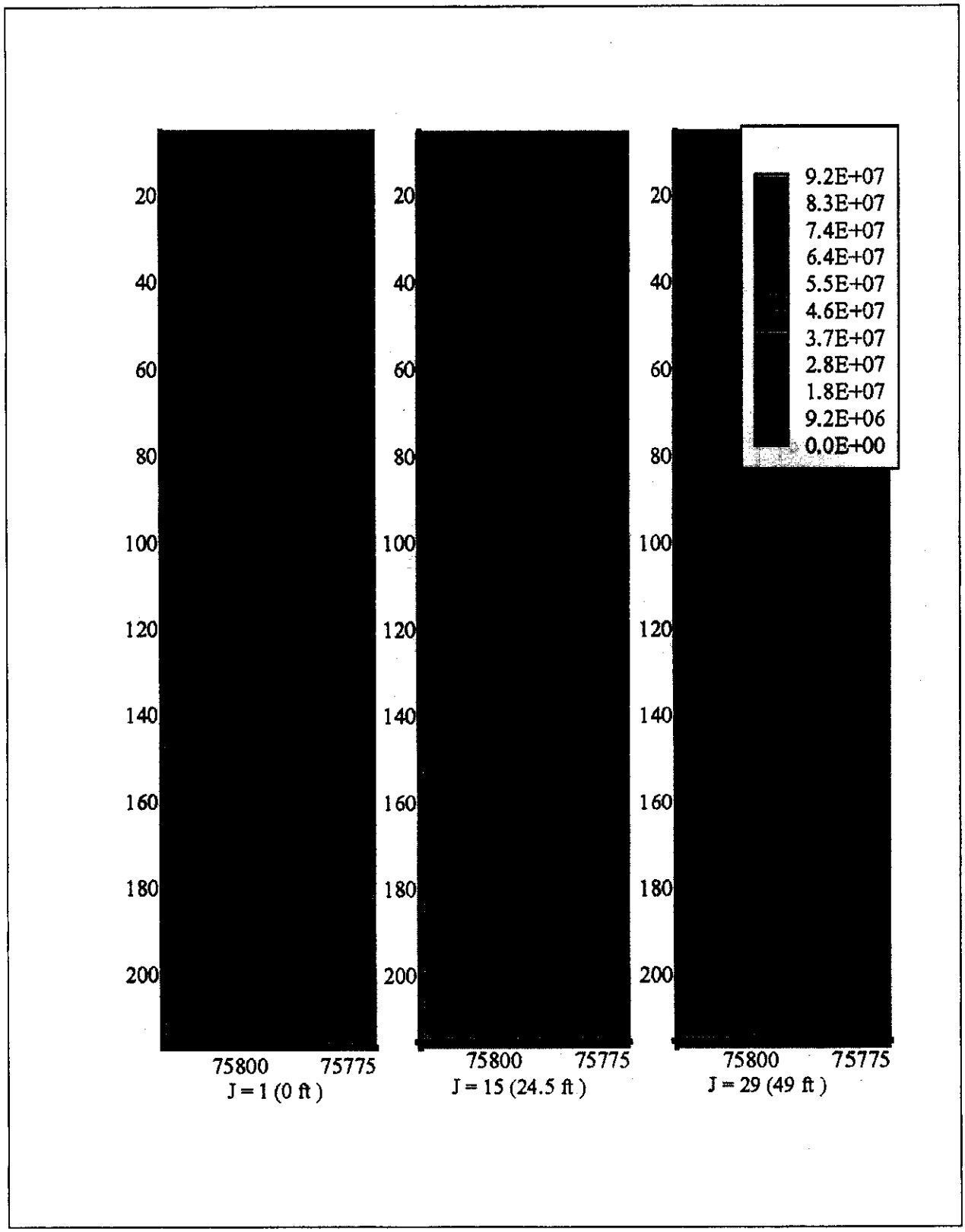


Figure E3.203. Tc-99 Mass Flux Results for Selected Nodes at the Bottom of Three-Dimensional Simulation Domain

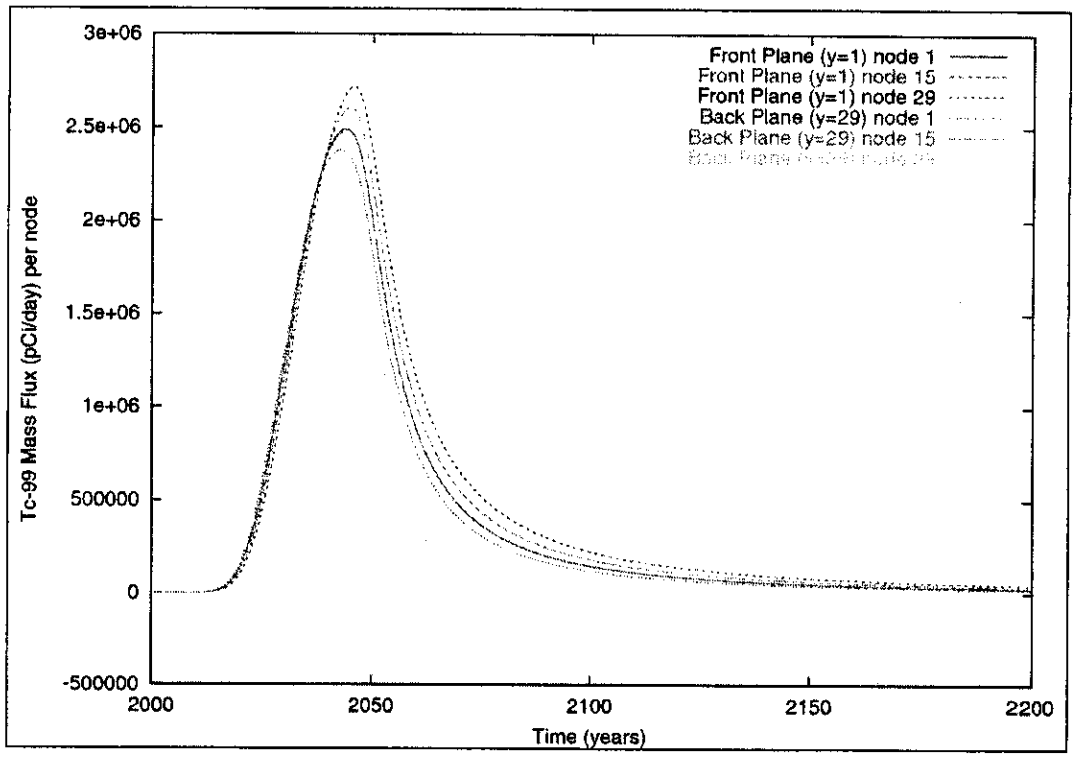


Figure E3.204. Comparison of Two-Dimensional and Three-Dimensional Simulation Results for Aqueous Fluxes at the Bottom of the Domain

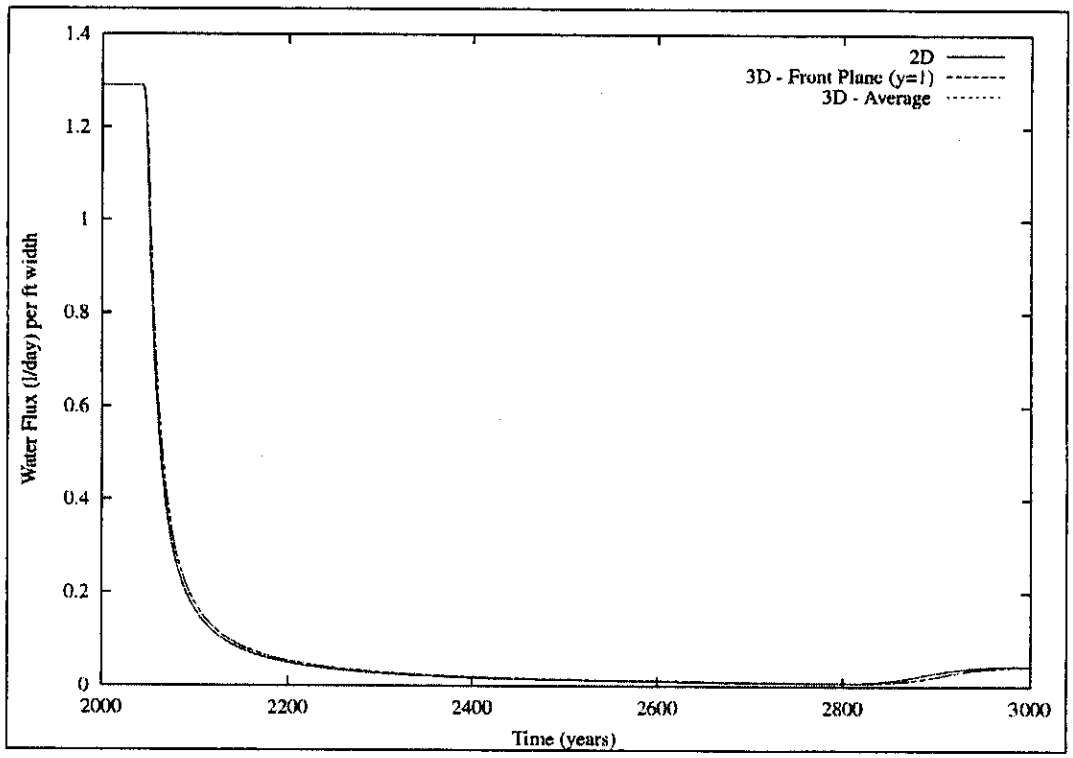
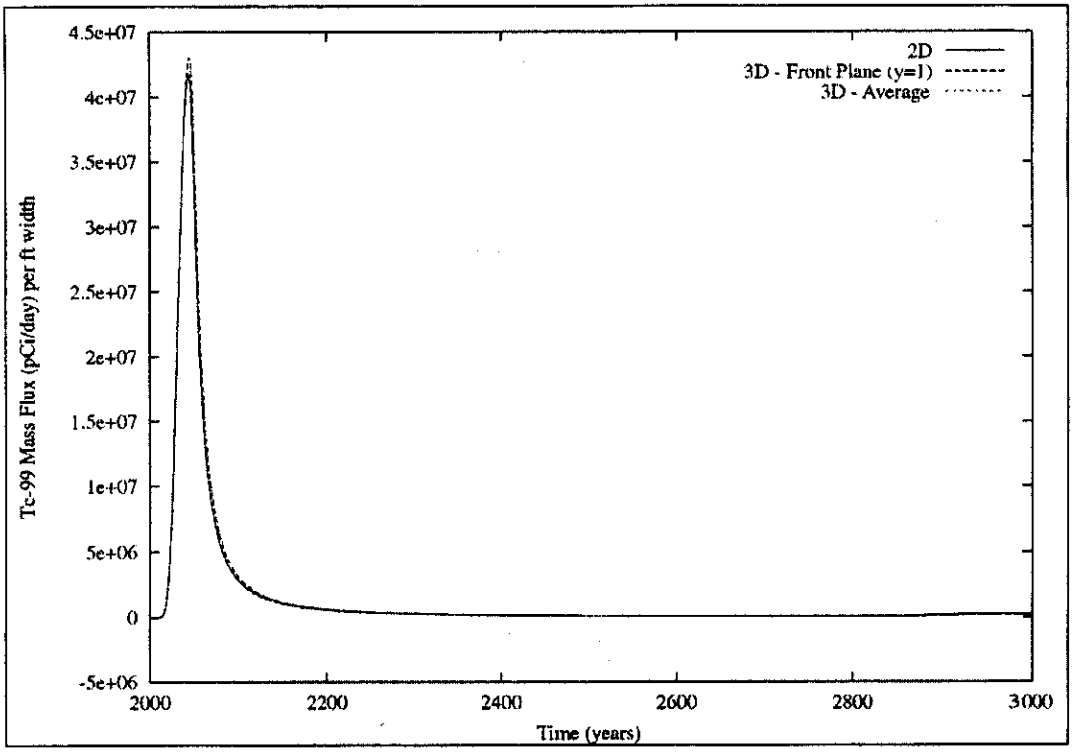


Figure E3.205. Comparison of Two-Dimensional and Three-Dimensional Simulation Results for Tc-99 Fluxes at the Bottom of the Domain



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ATTACHMENT E4

SOLUTE TRANSPORT TIME SEQUENCES

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Figure E4.1. Tc-99 Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

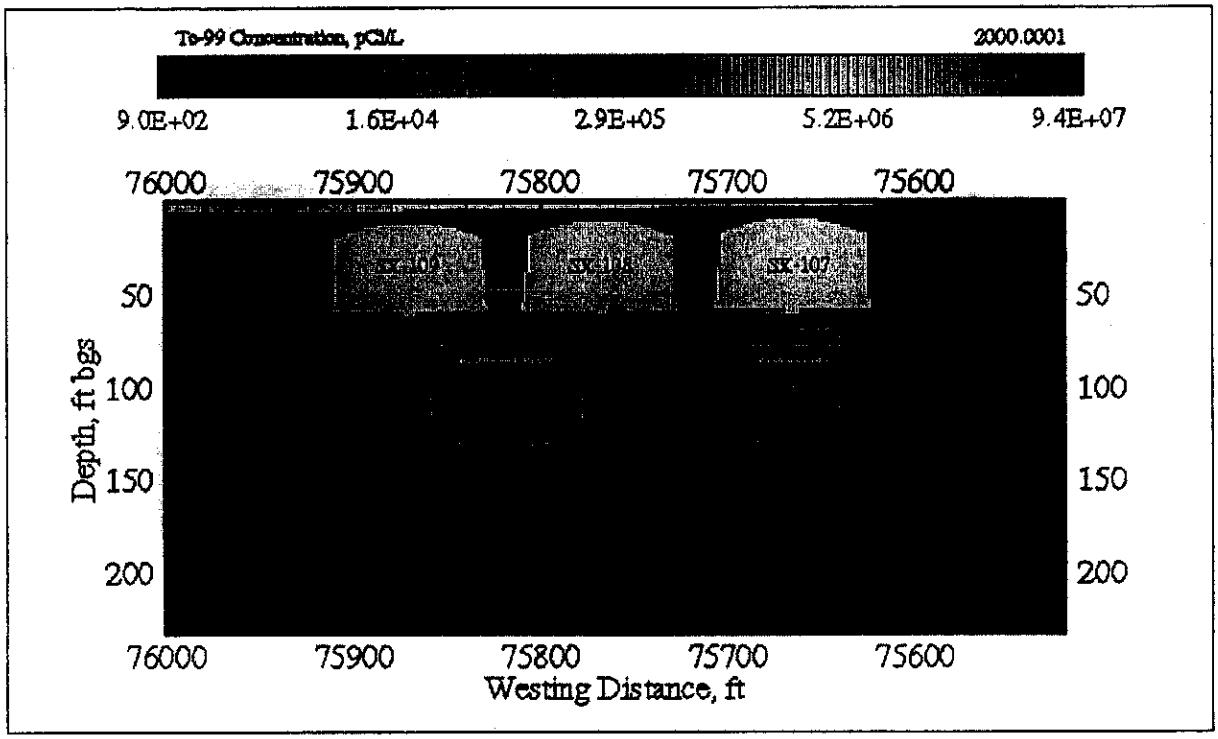


Figure E4.2. Tc-99 Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

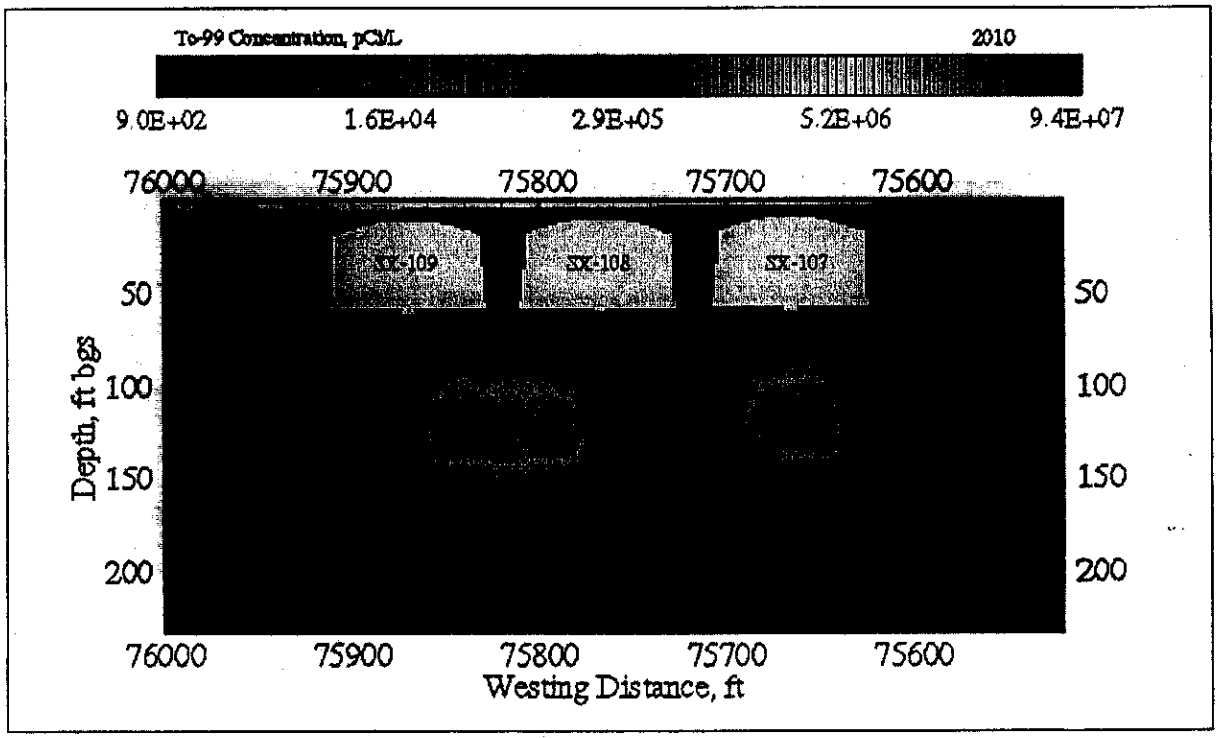


Figure E4.3. Tc-99 Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

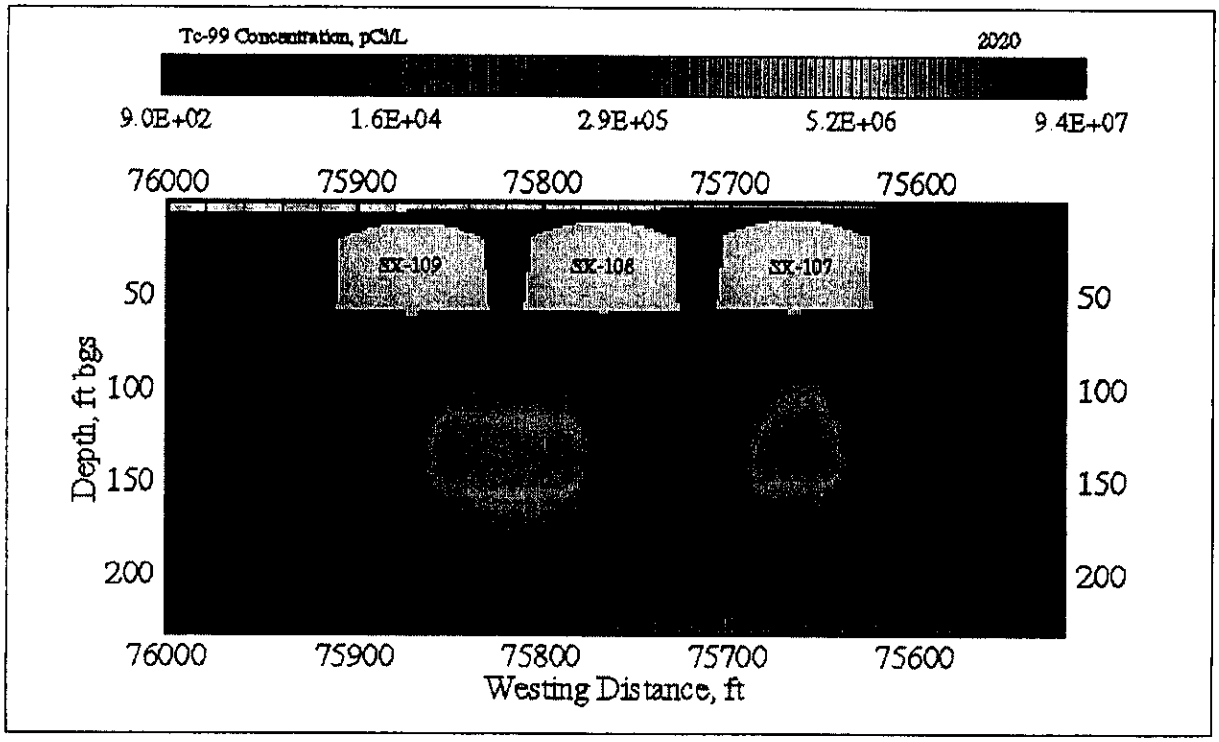


Figure E4.4. Tc-99 Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

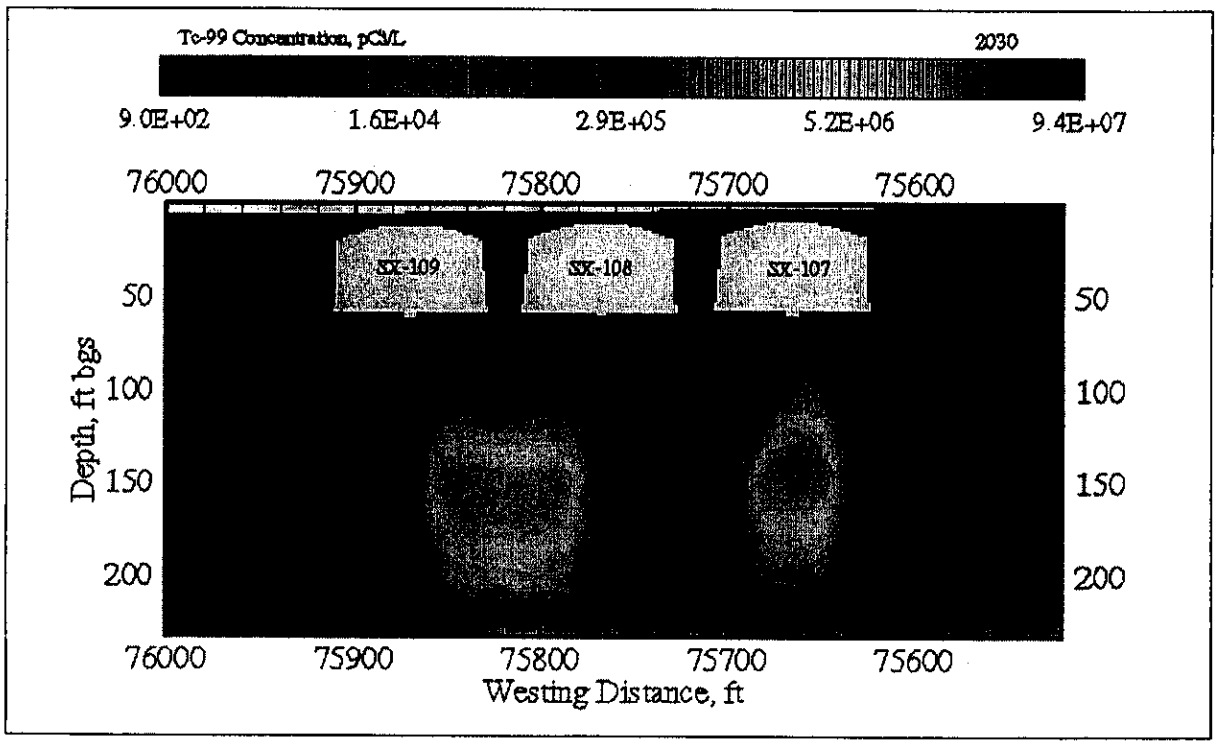


Figure E4.5. Tc-99 Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

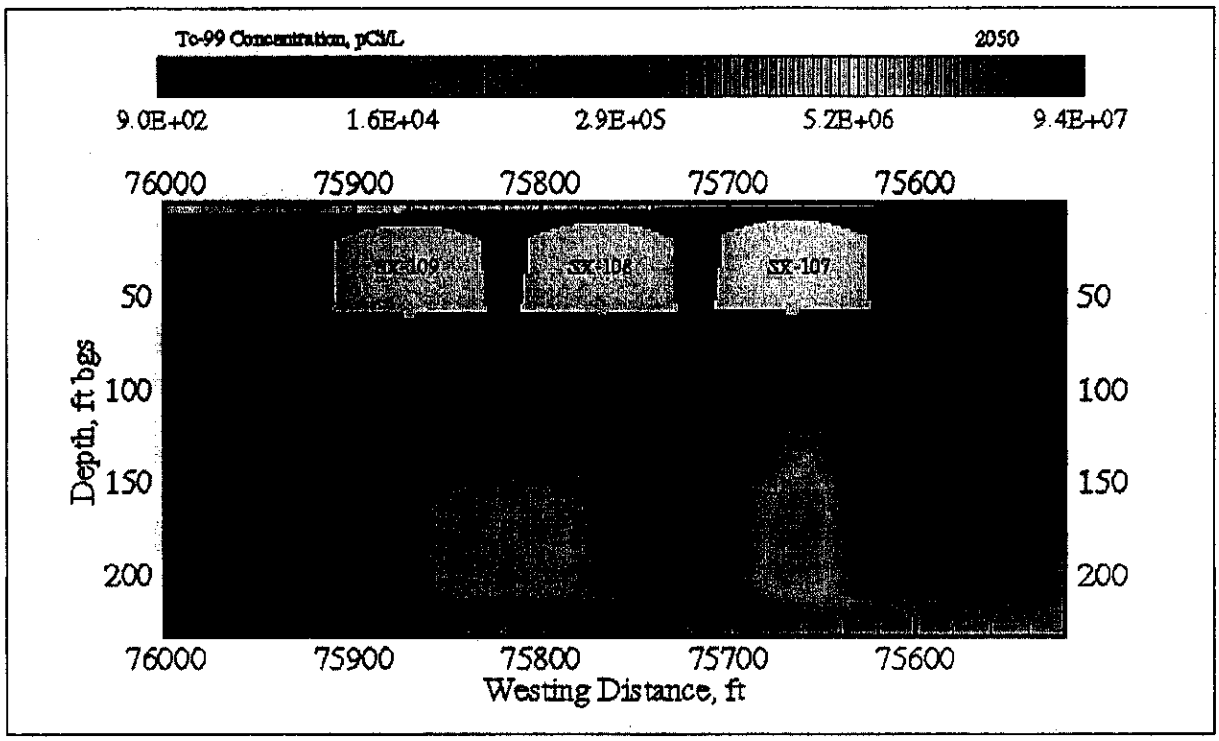


Figure E4.6. Tc-99 Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

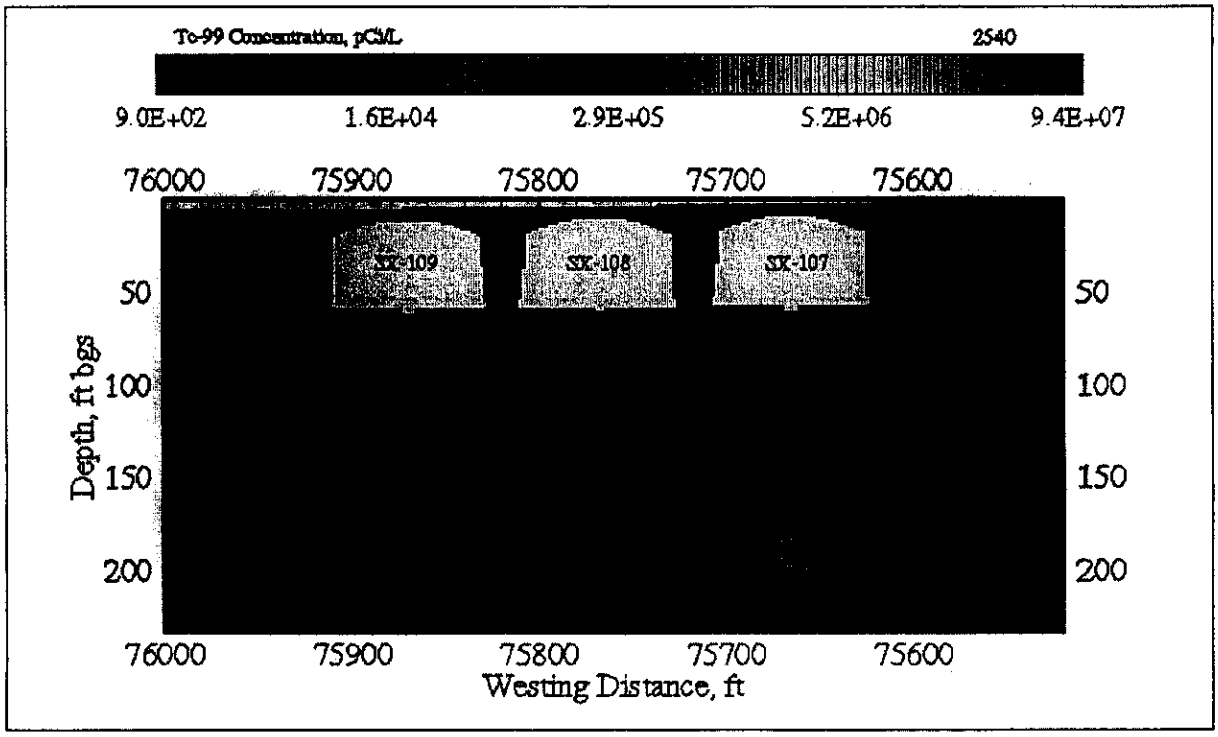


Figure E4.7. Tc-99 Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

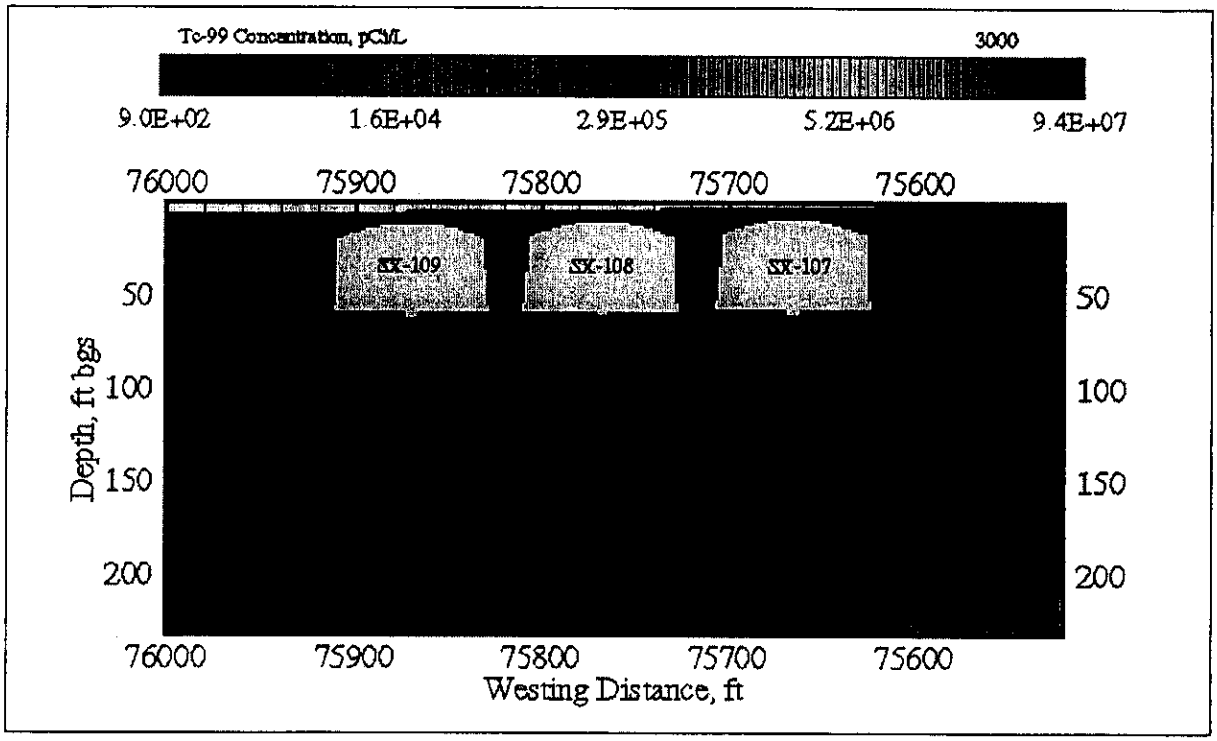


Figure E4.8. Cr Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

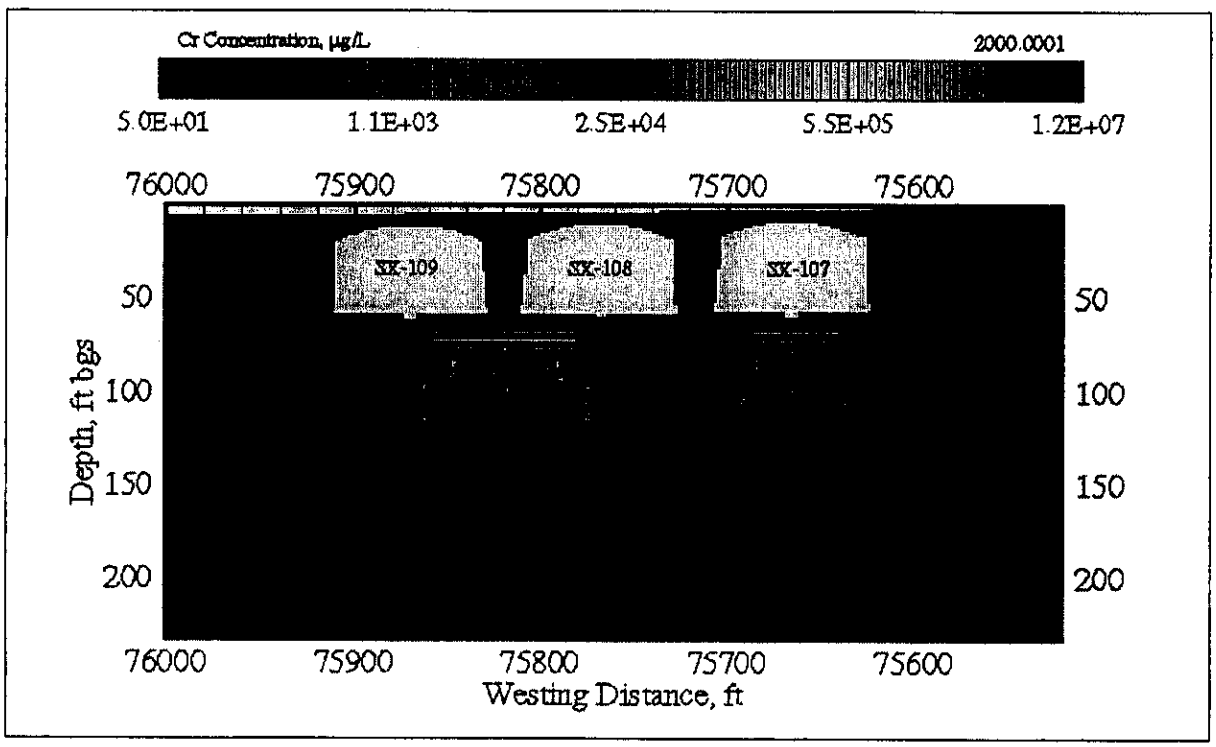


Figure E4.9. Cr Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

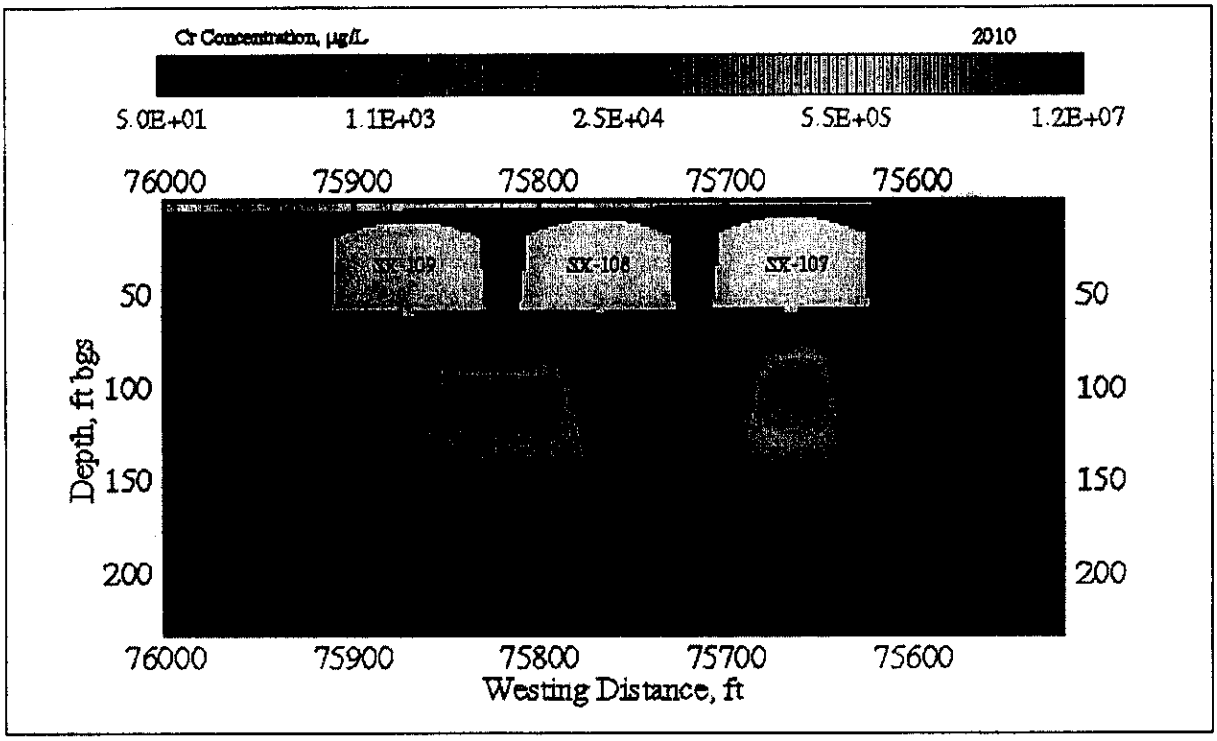


Figure E4.10. Cr Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

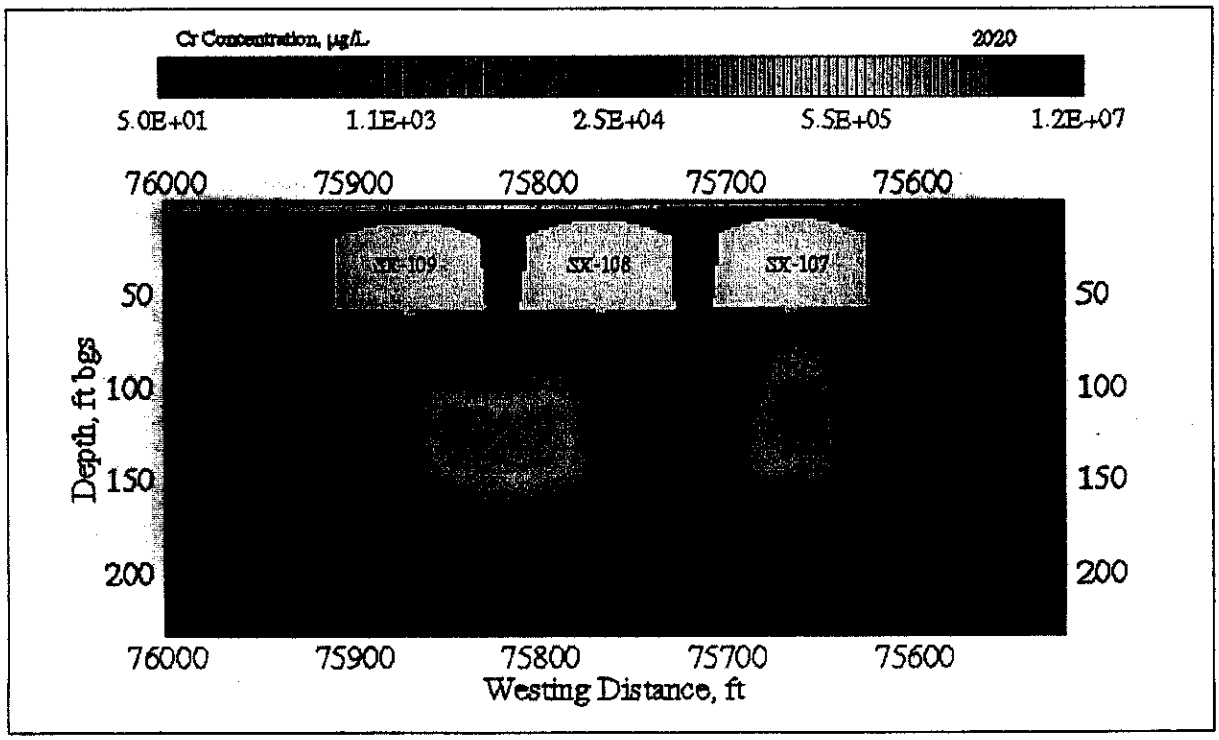


Figure E4.11. Cr Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

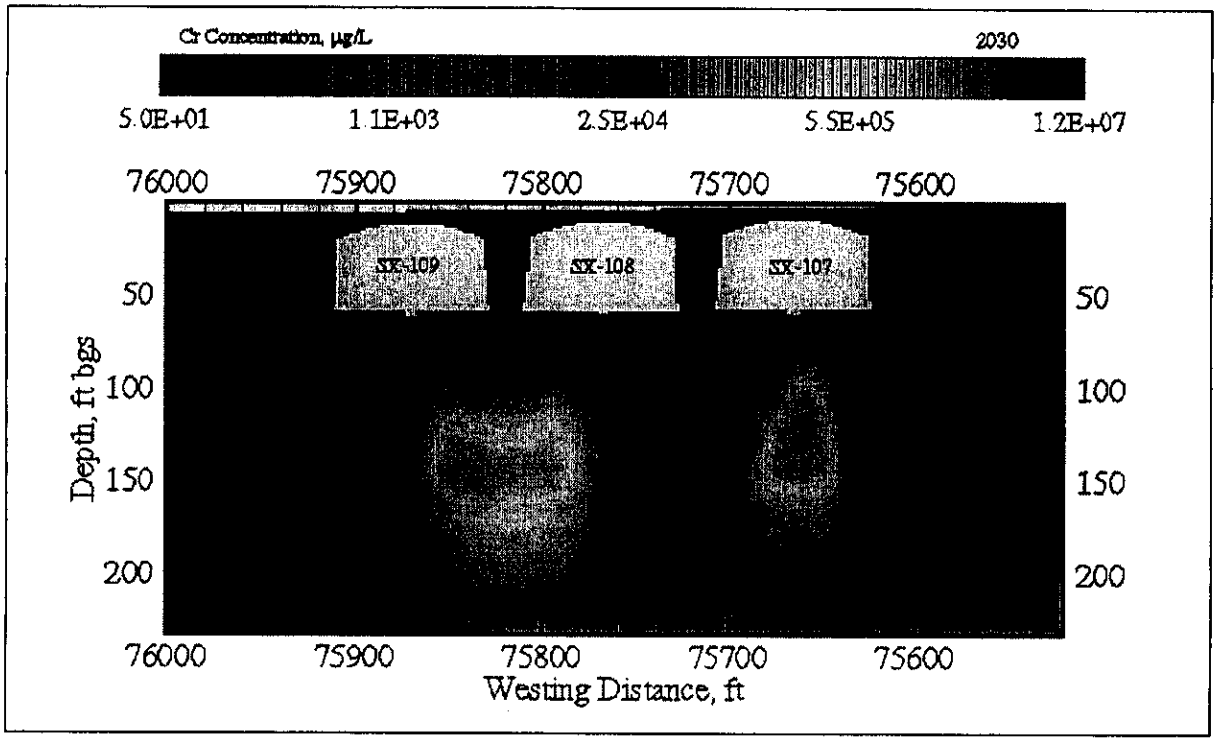


Figure E4.12. Cr Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

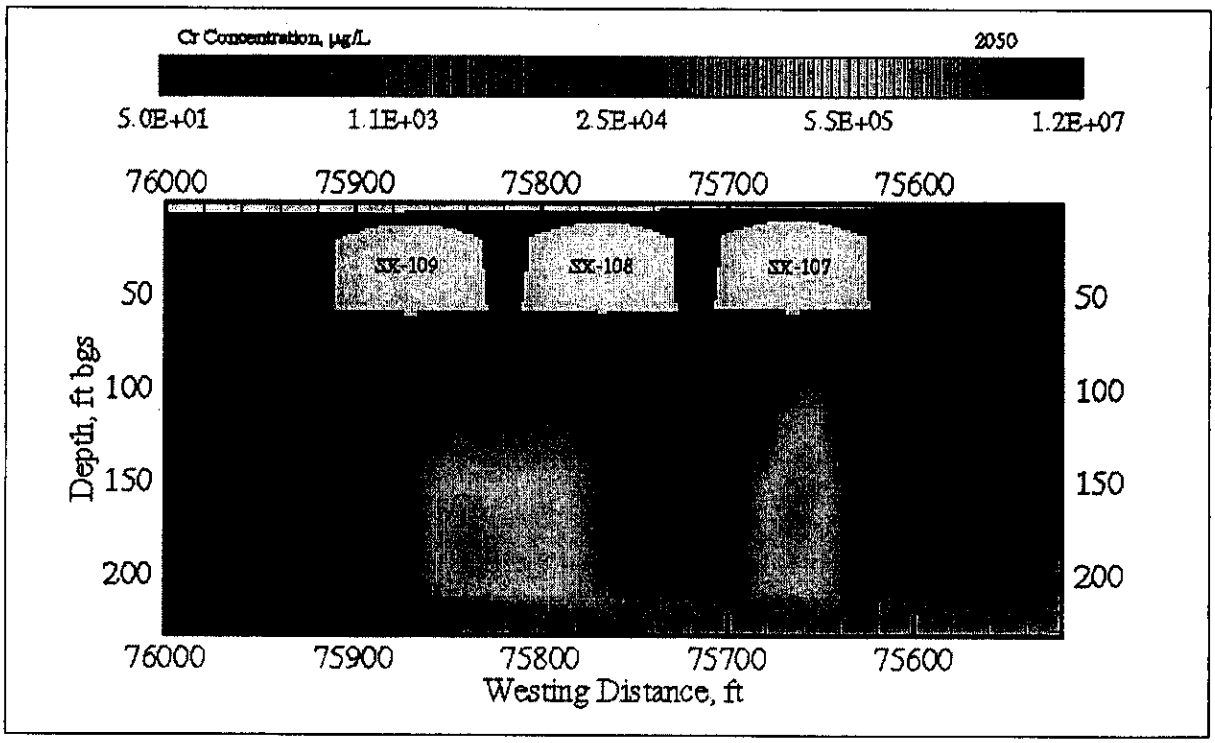


Figure E4.13. Cr Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

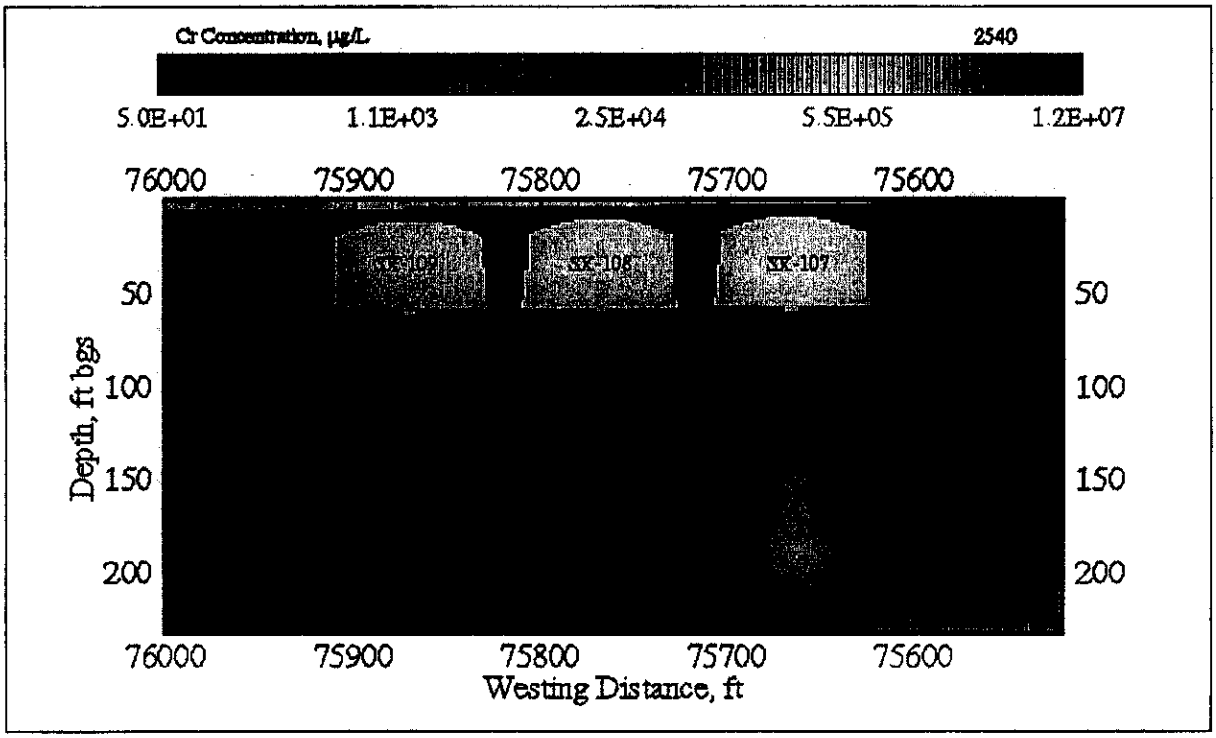


Figure E4.14. Cr Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

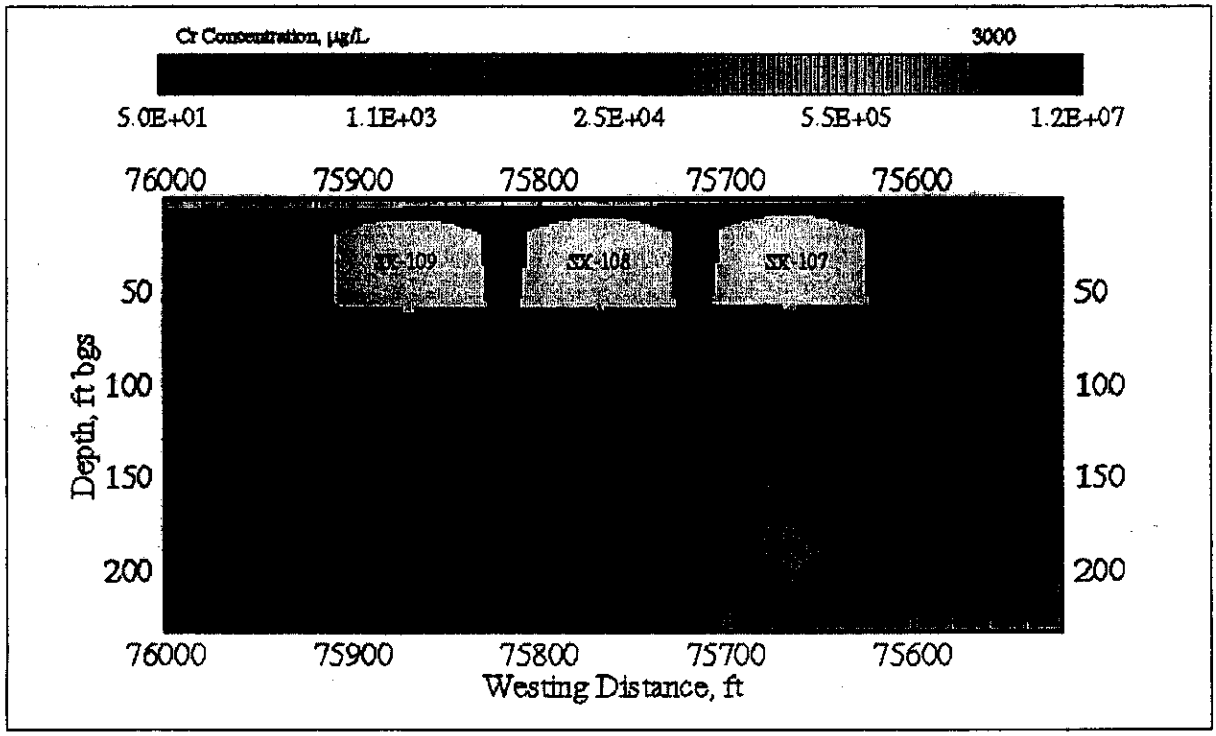


Figure E4.15. NO_3 Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

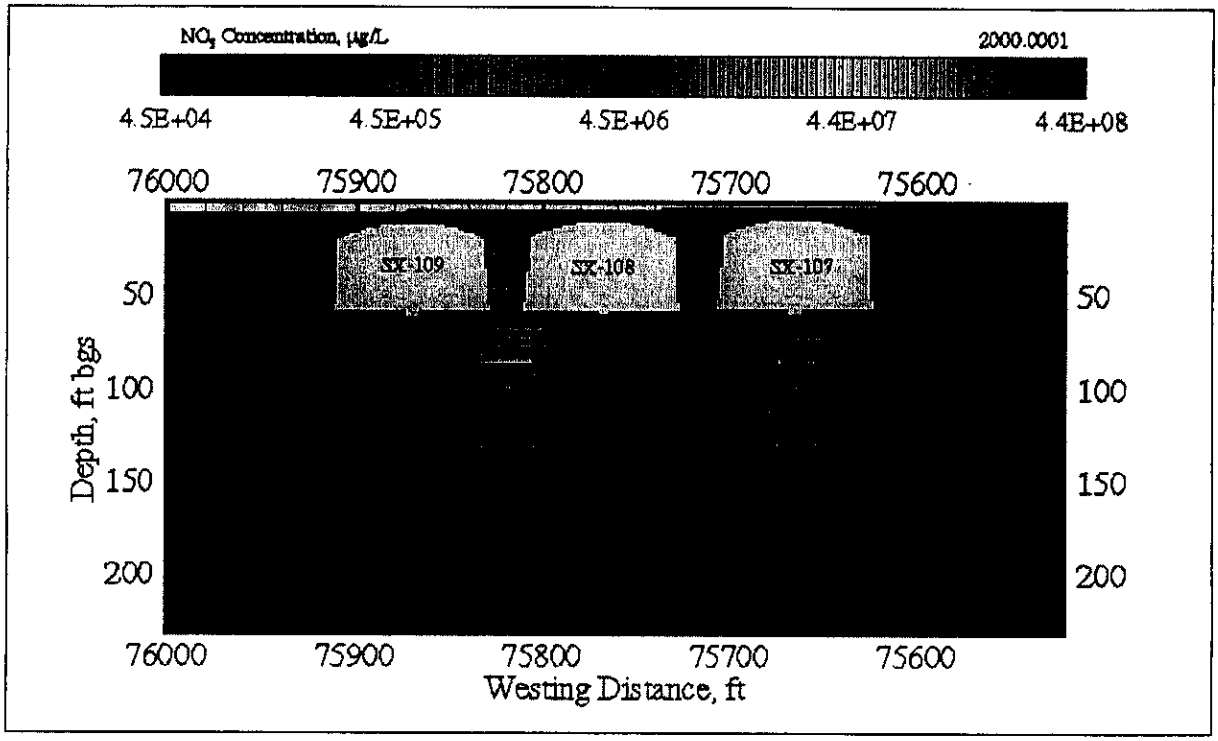


Figure E4.16. NO_3 Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

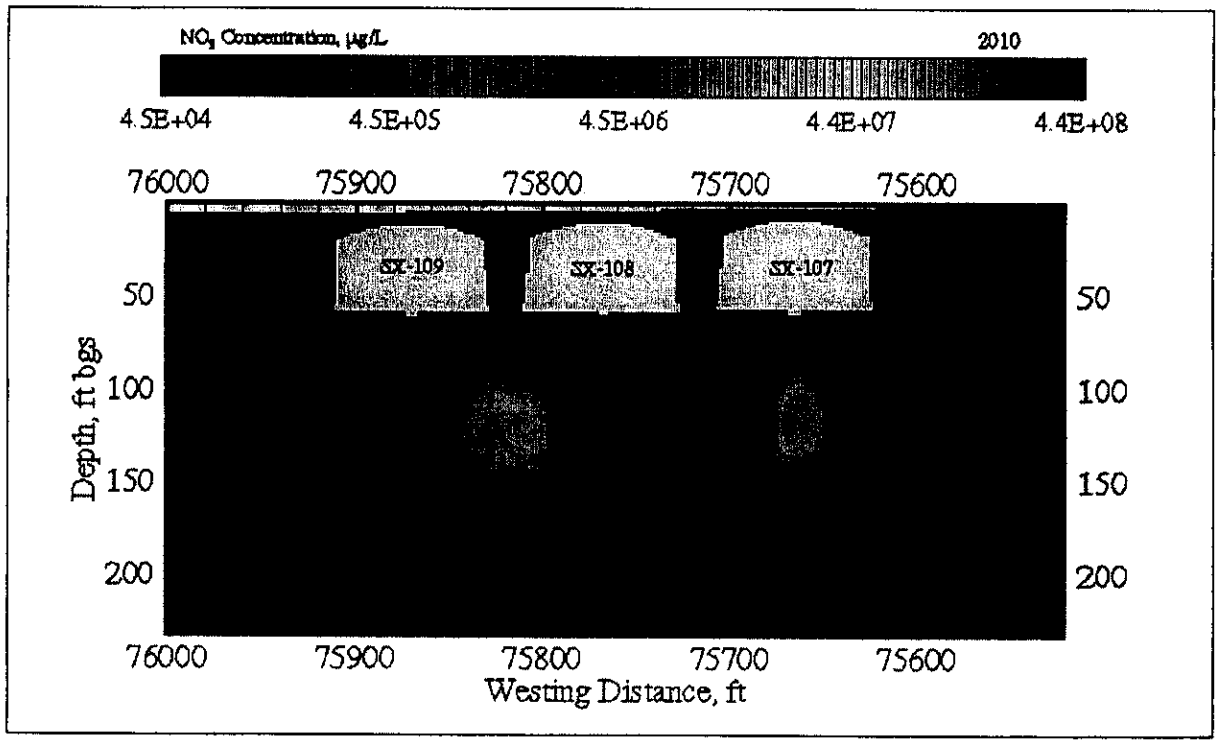


Figure E4.17. NO_3 Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

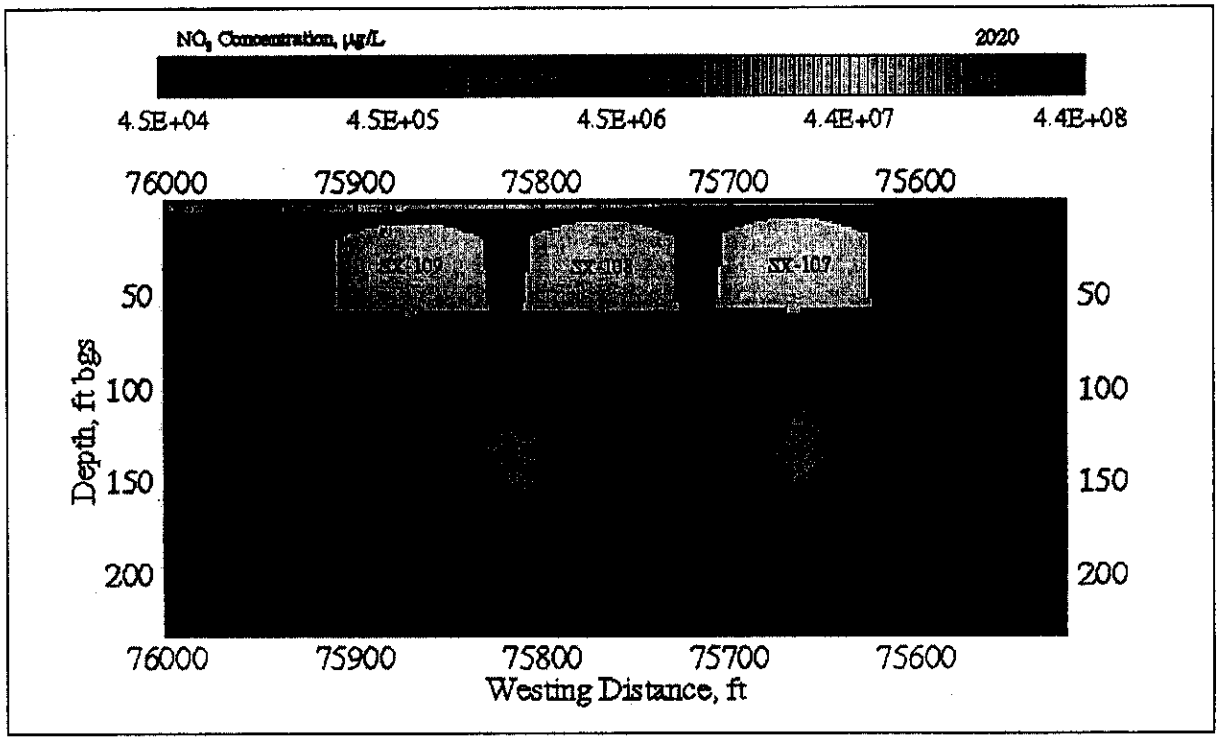


Figure E4.18. NO_3 Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

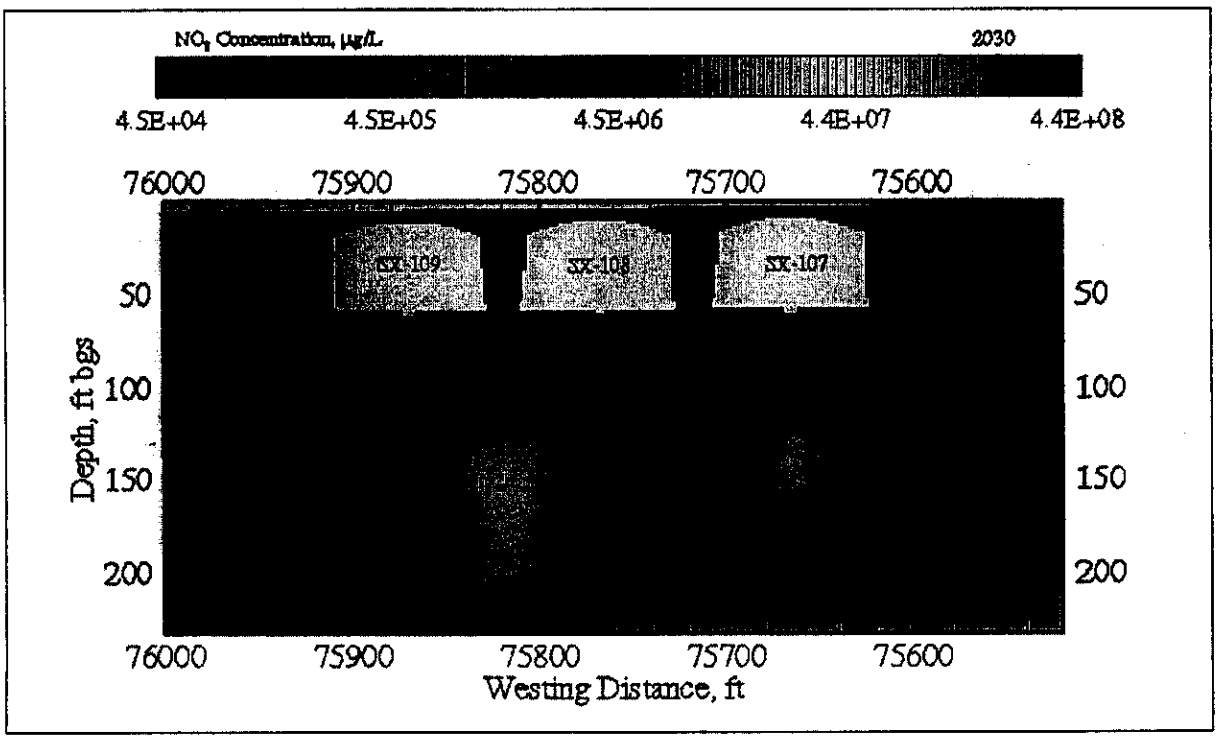


Figure E4.19. NO_3 Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

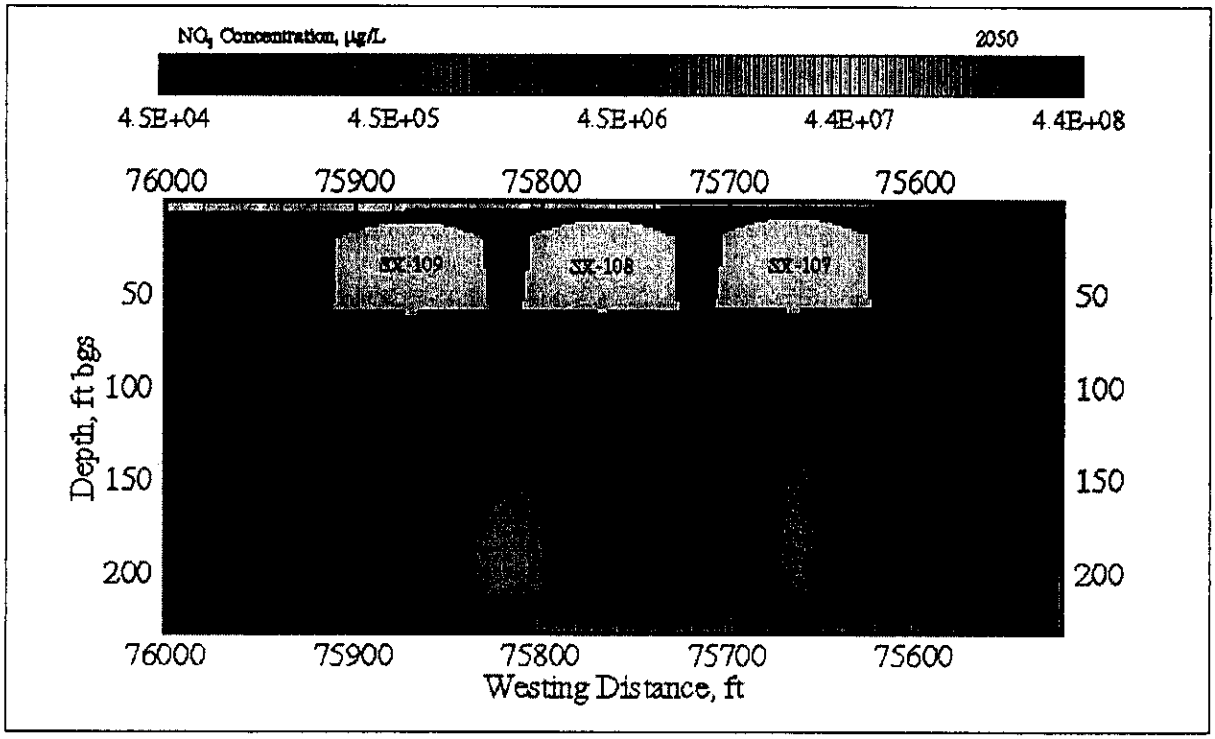


Figure E4.20. NO_3 Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

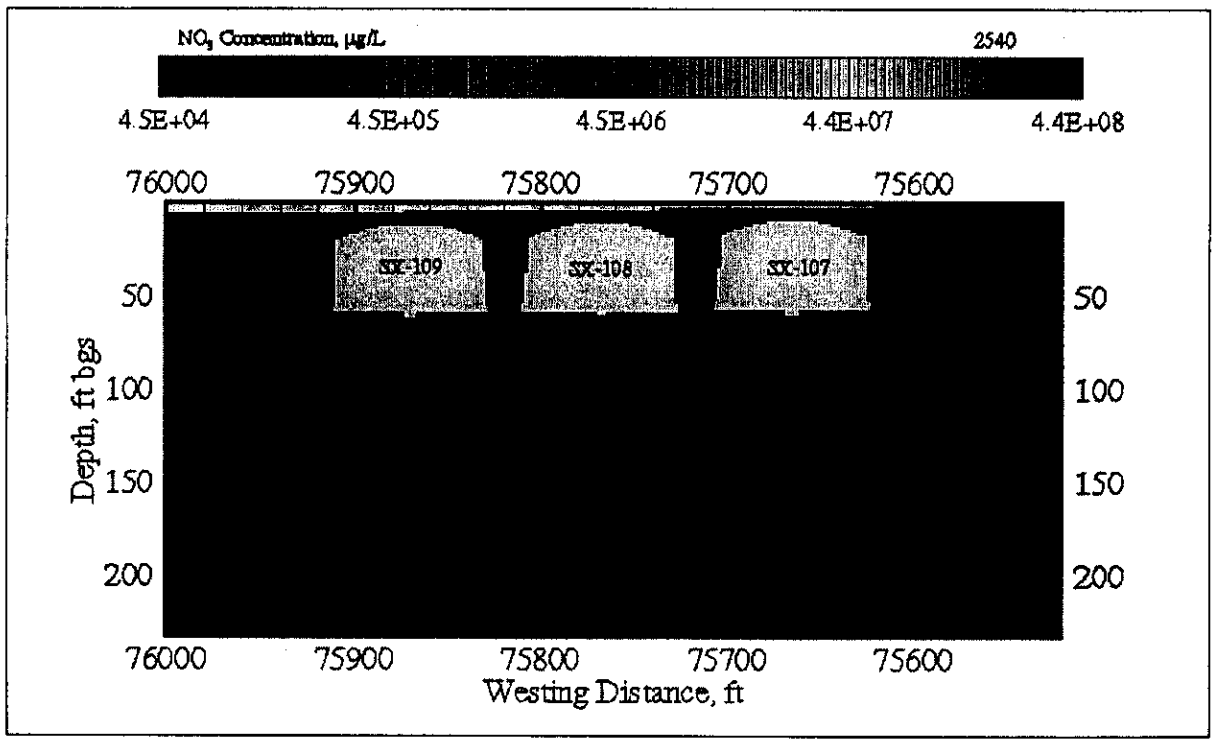


Figure E4.21. NO_3 Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section SX-DD' (SX-107, -108, -109)

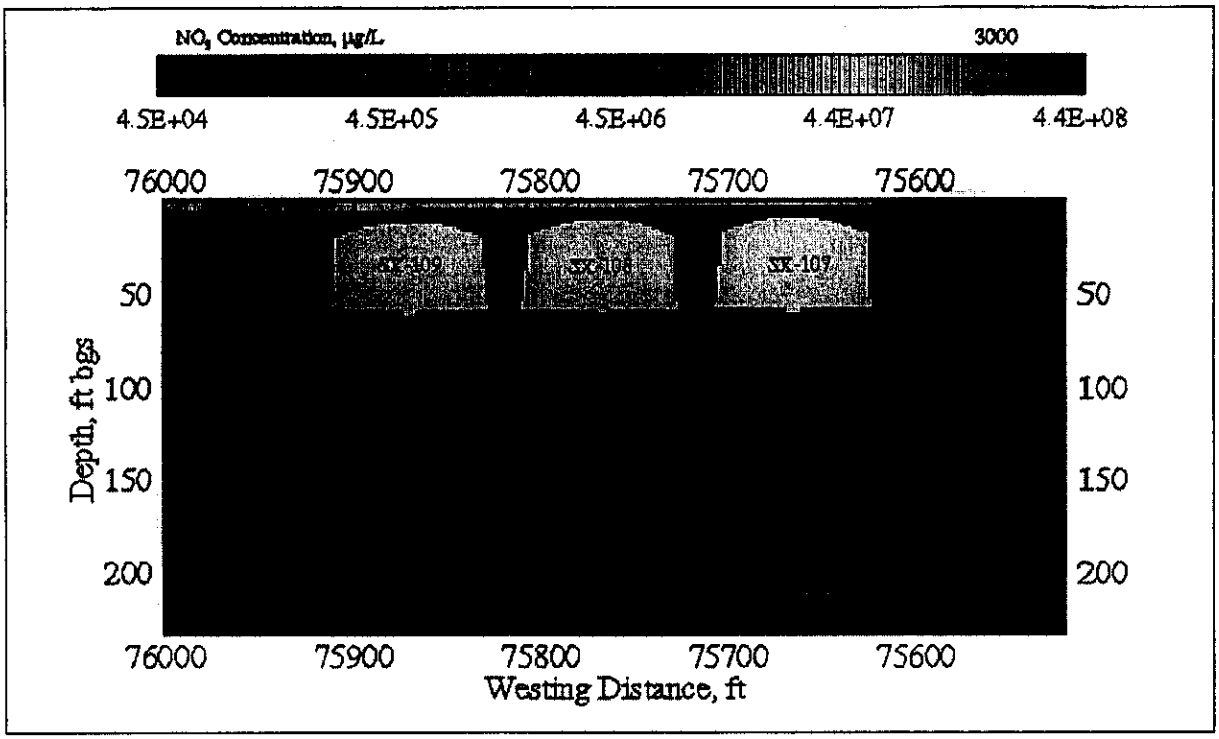


Figure E4.22. Tc-99 Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

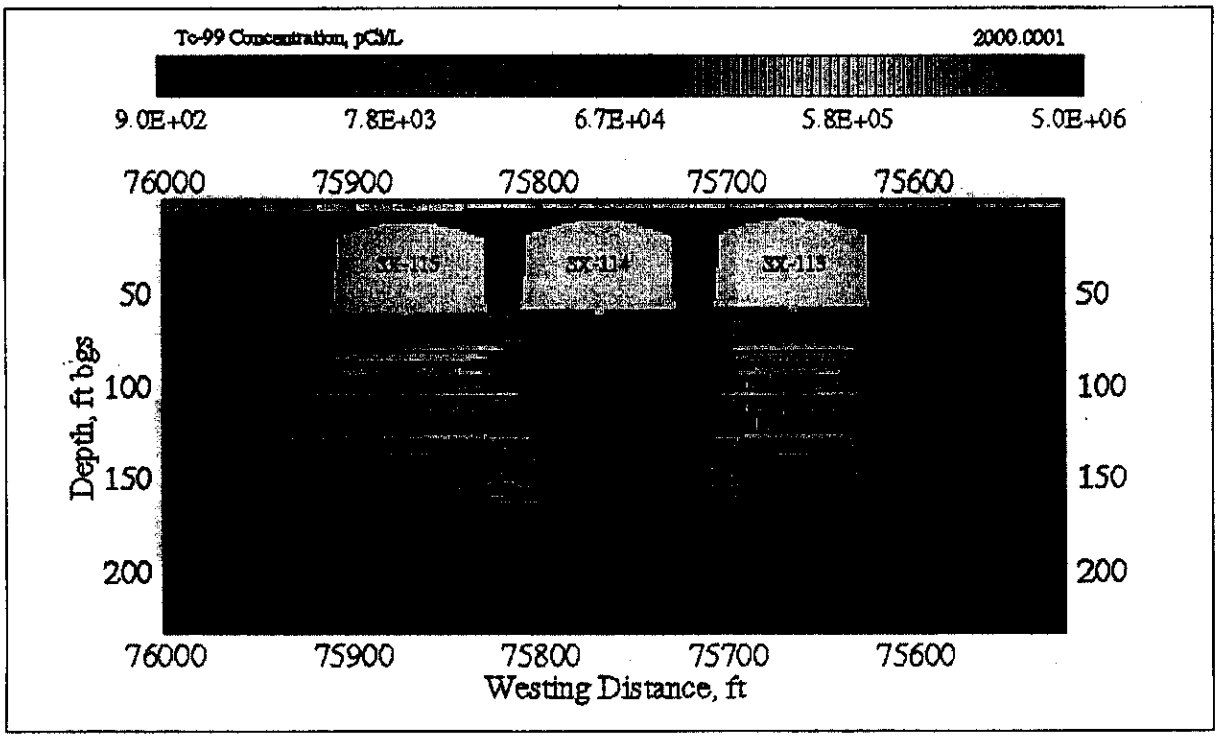


Figure E4.23. Tc-99 Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

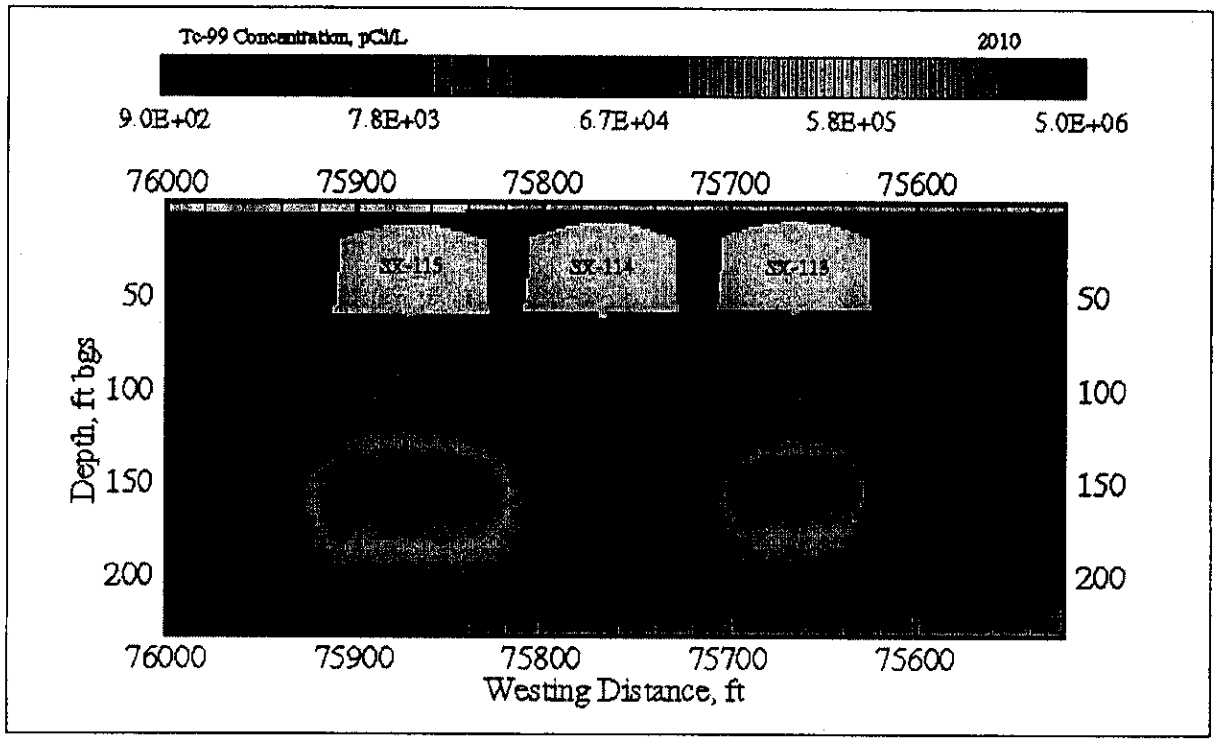


Figure E4.24. Tc-99 Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

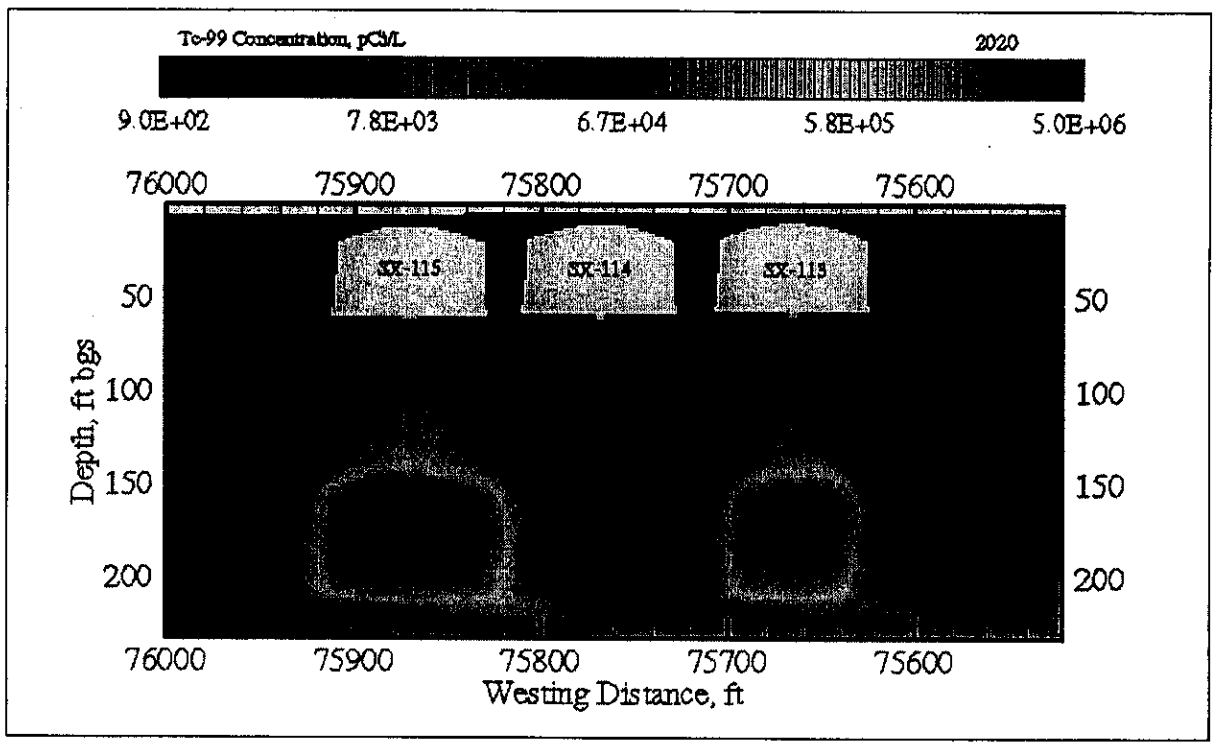


Figure E4.25. Tc-99 Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

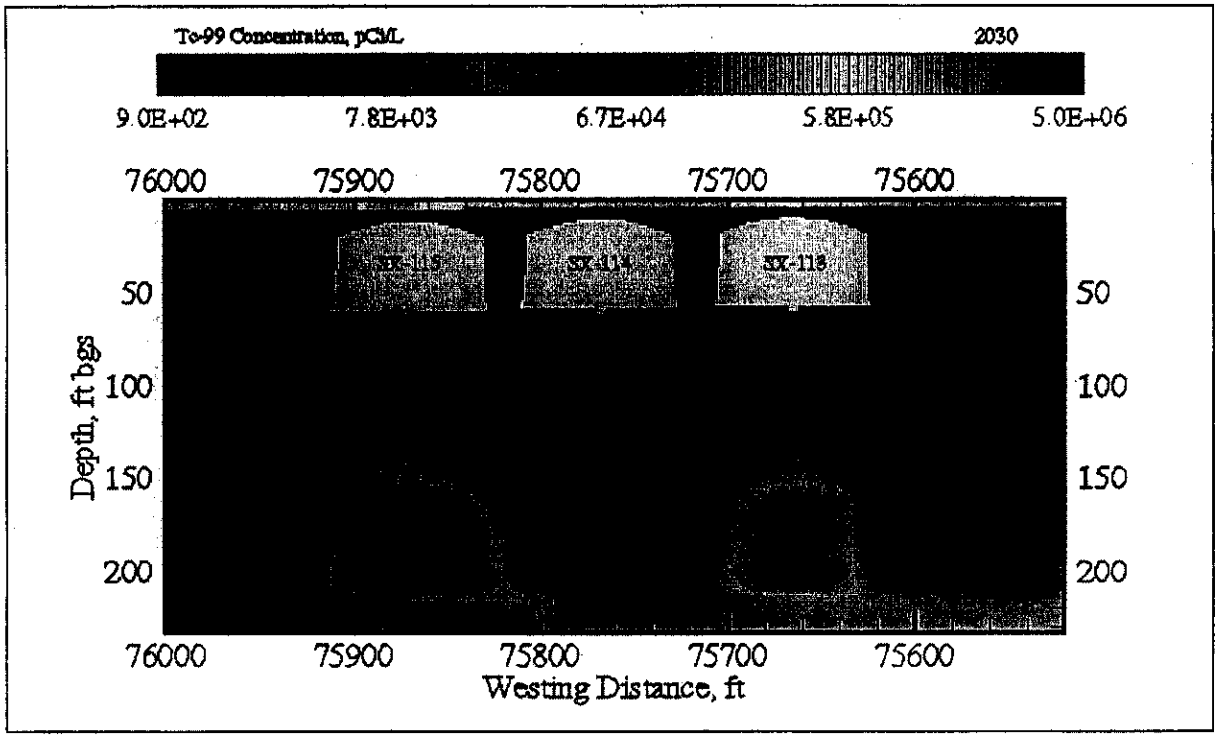


Figure E4.26. Tc-99 Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

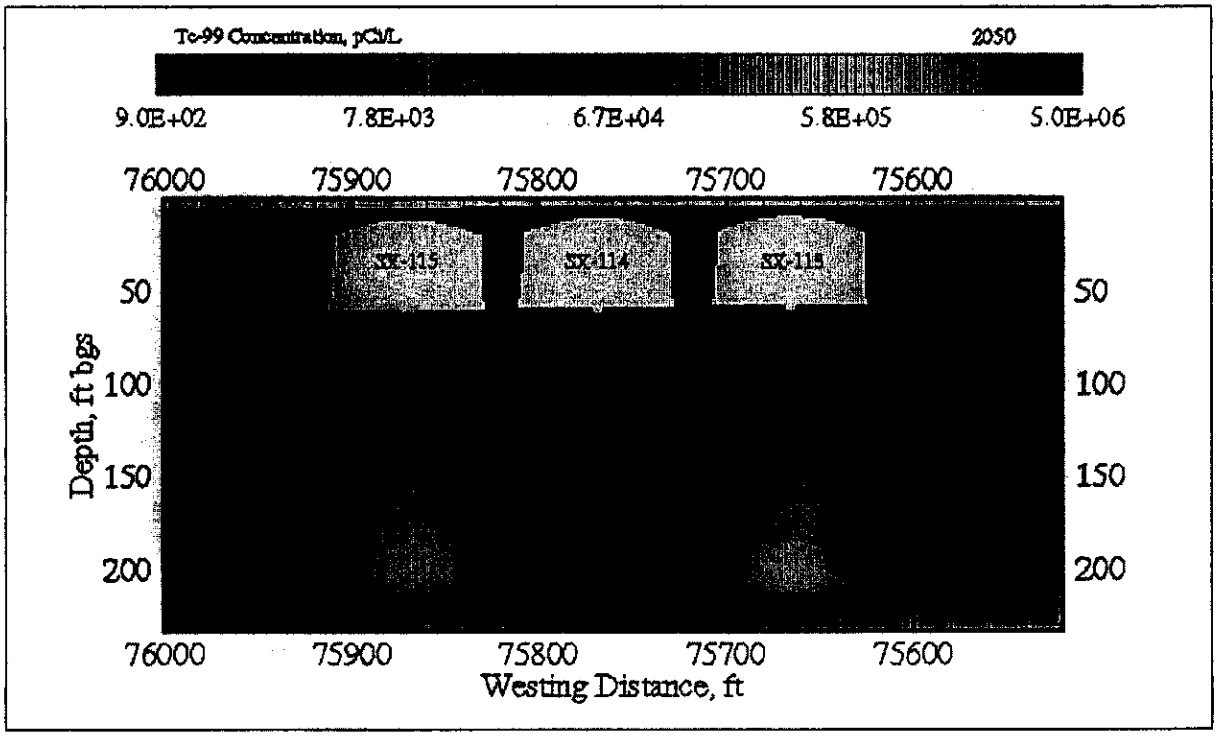


Figure E4.27. Tc-99 Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

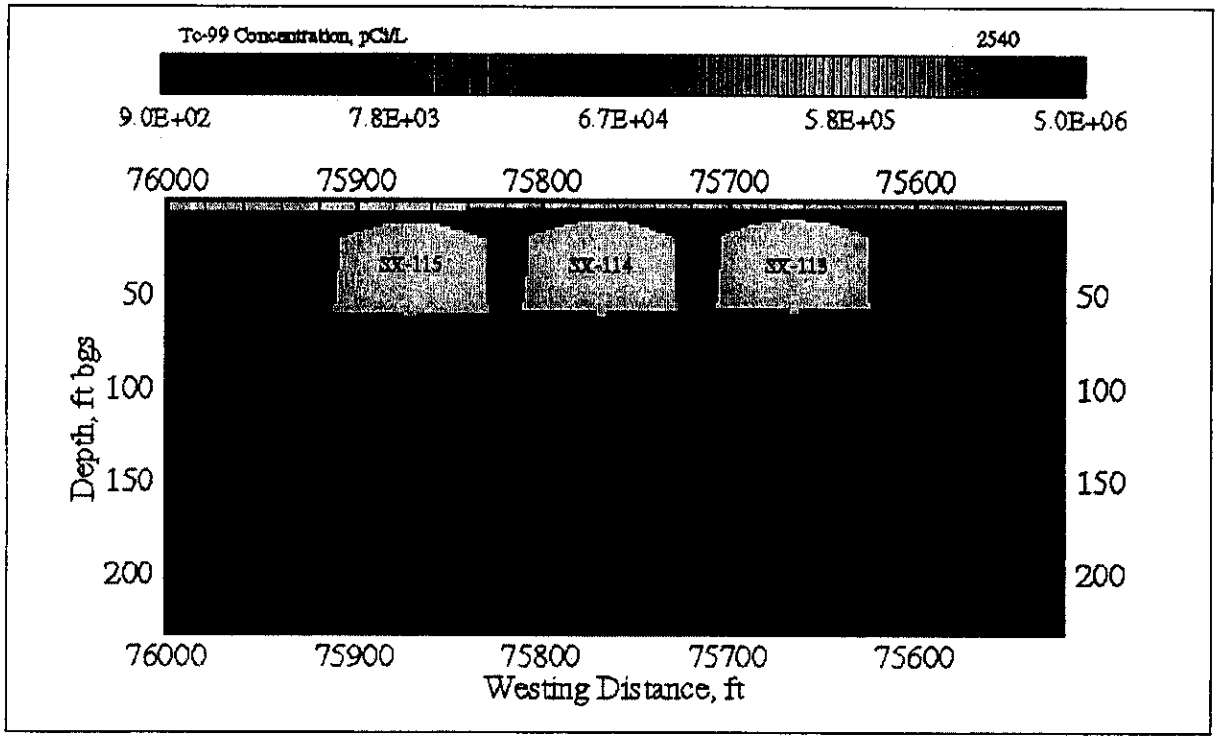


Figure E4.28. Tc-99 Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

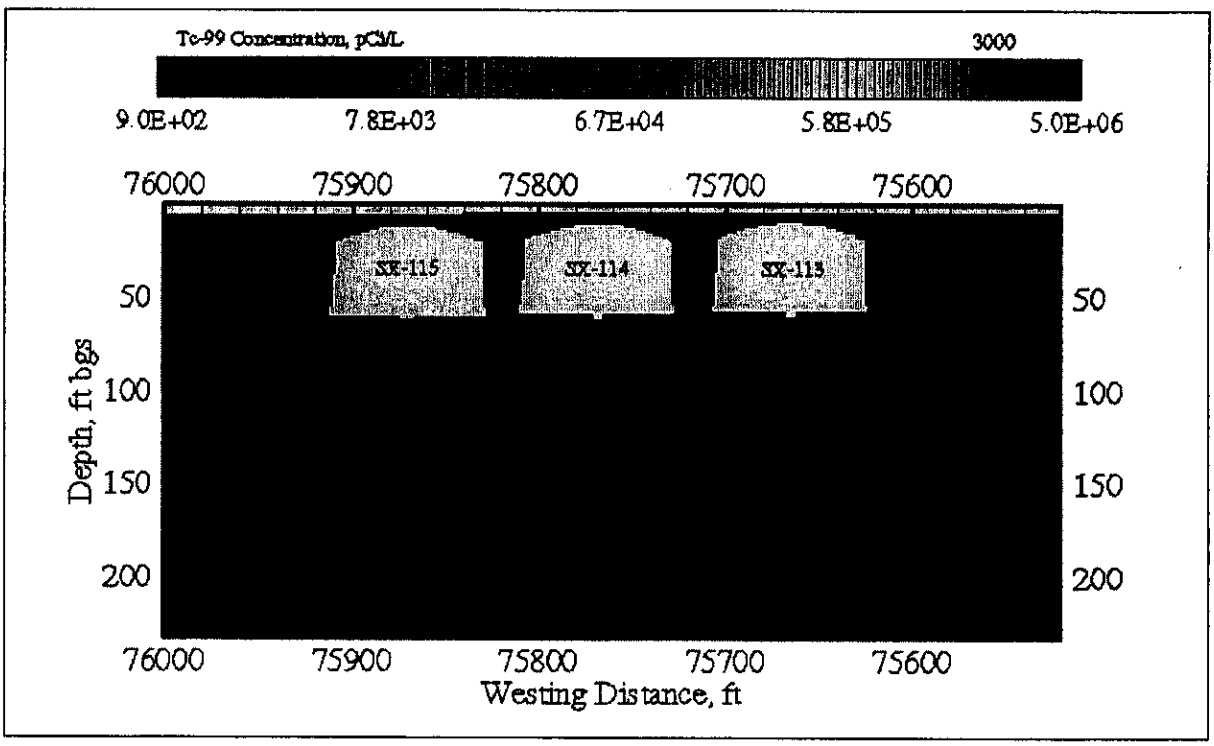


Figure E4.29. Cr Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

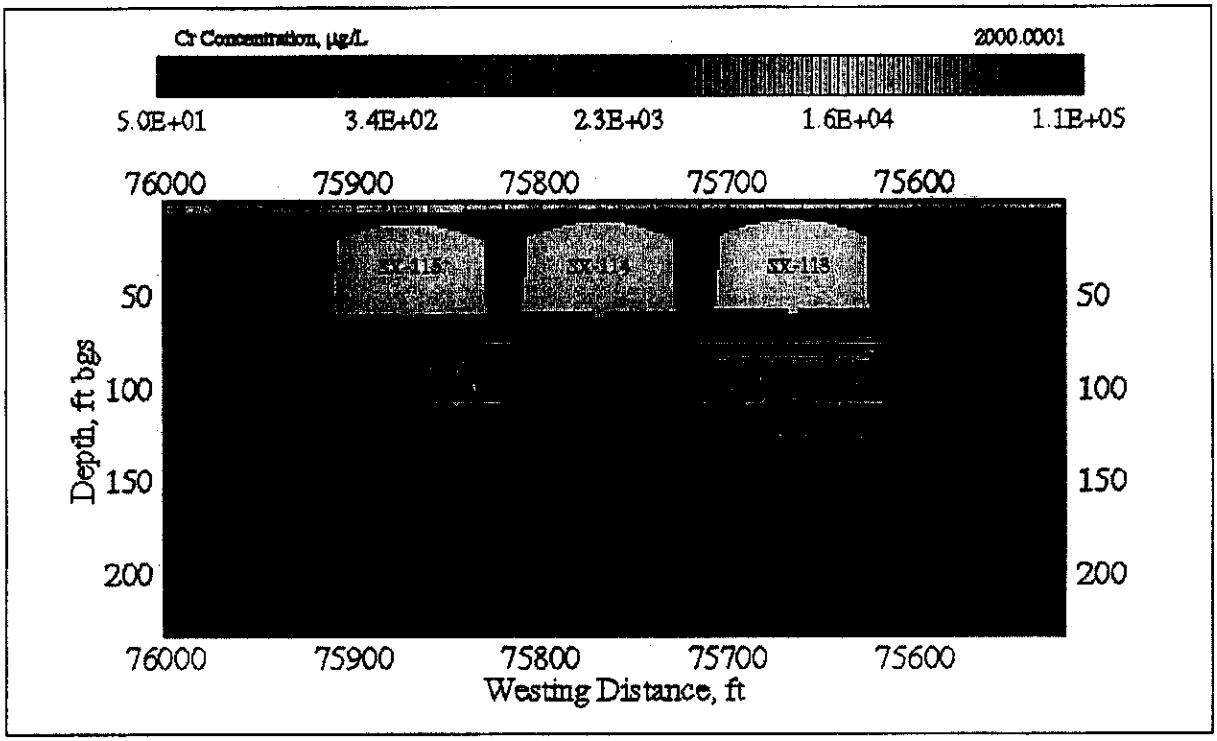


Figure E4.30. Cr Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

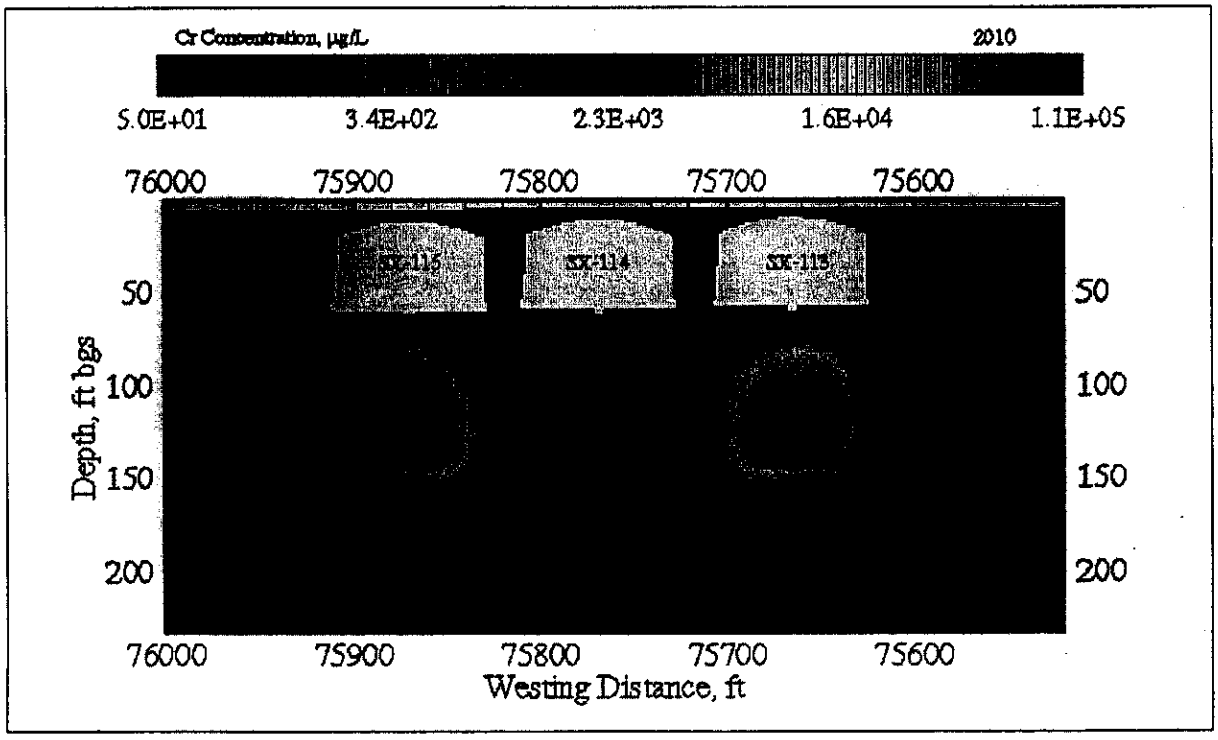


Figure E4.31. Cr Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

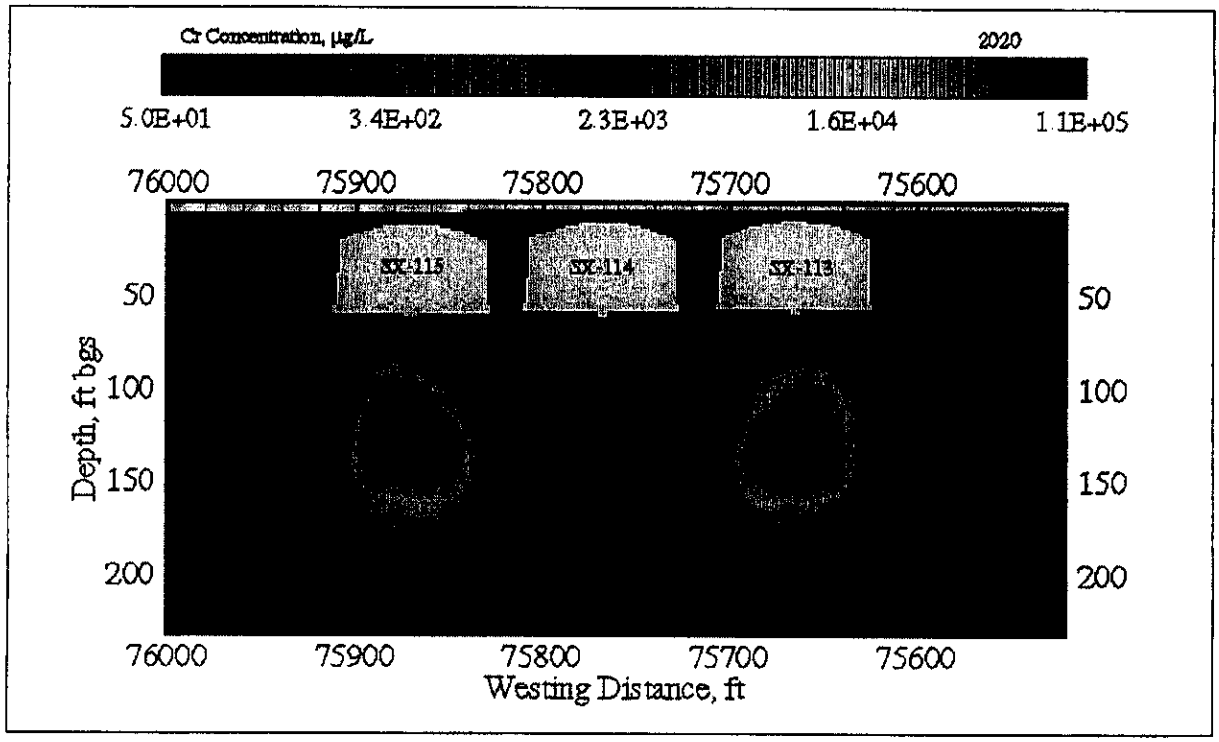


Figure E4.32. Cr Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

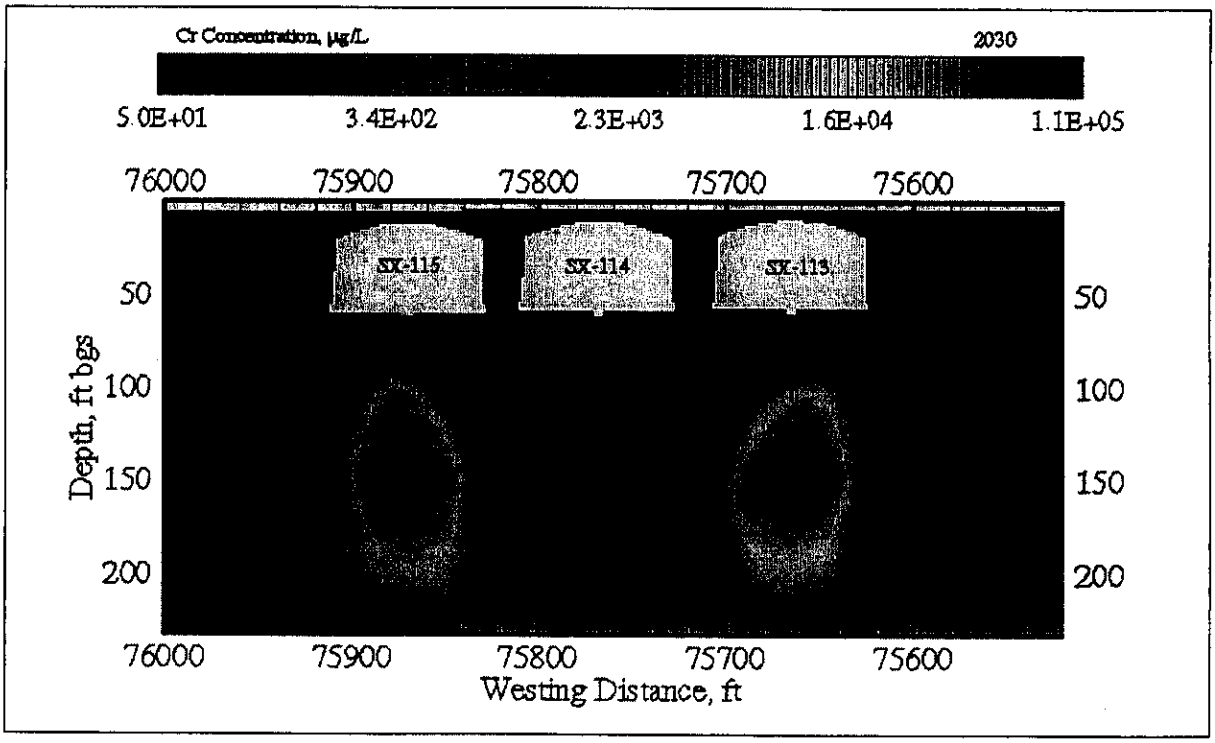


Figure E4.33. Cr Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

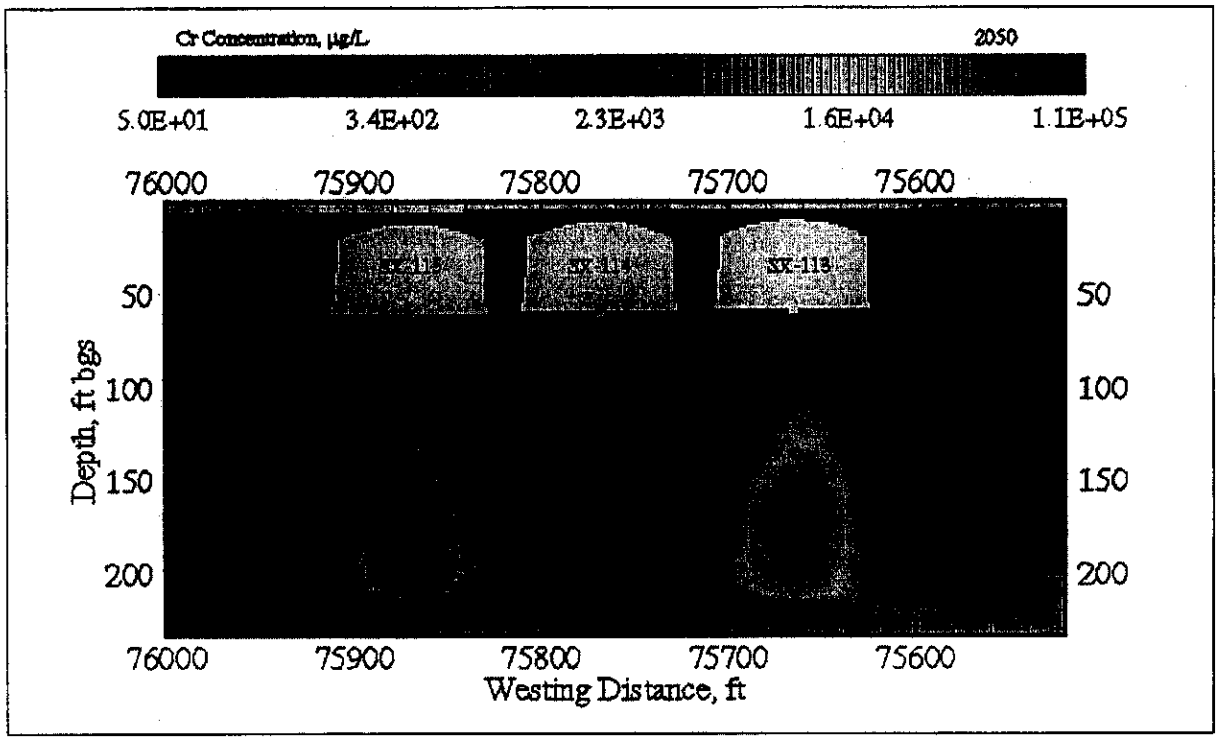


Figure E4.34. Cr Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

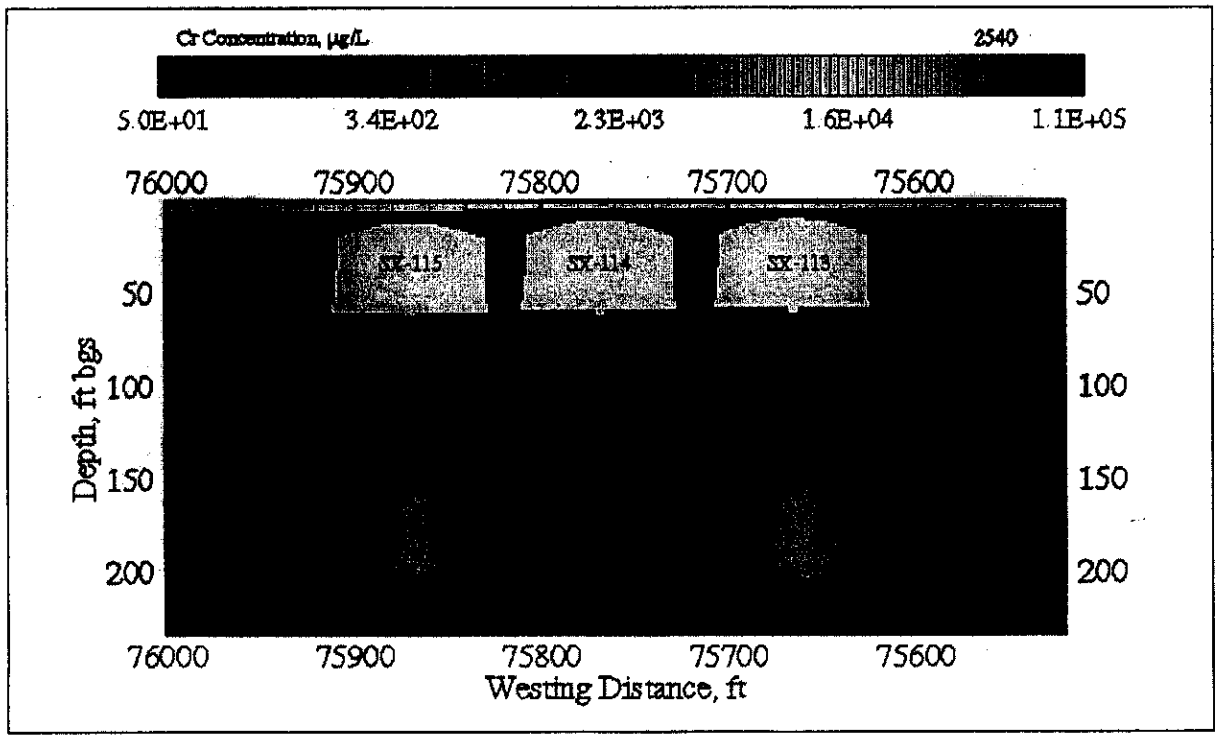


Figure E4.35. Cr Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

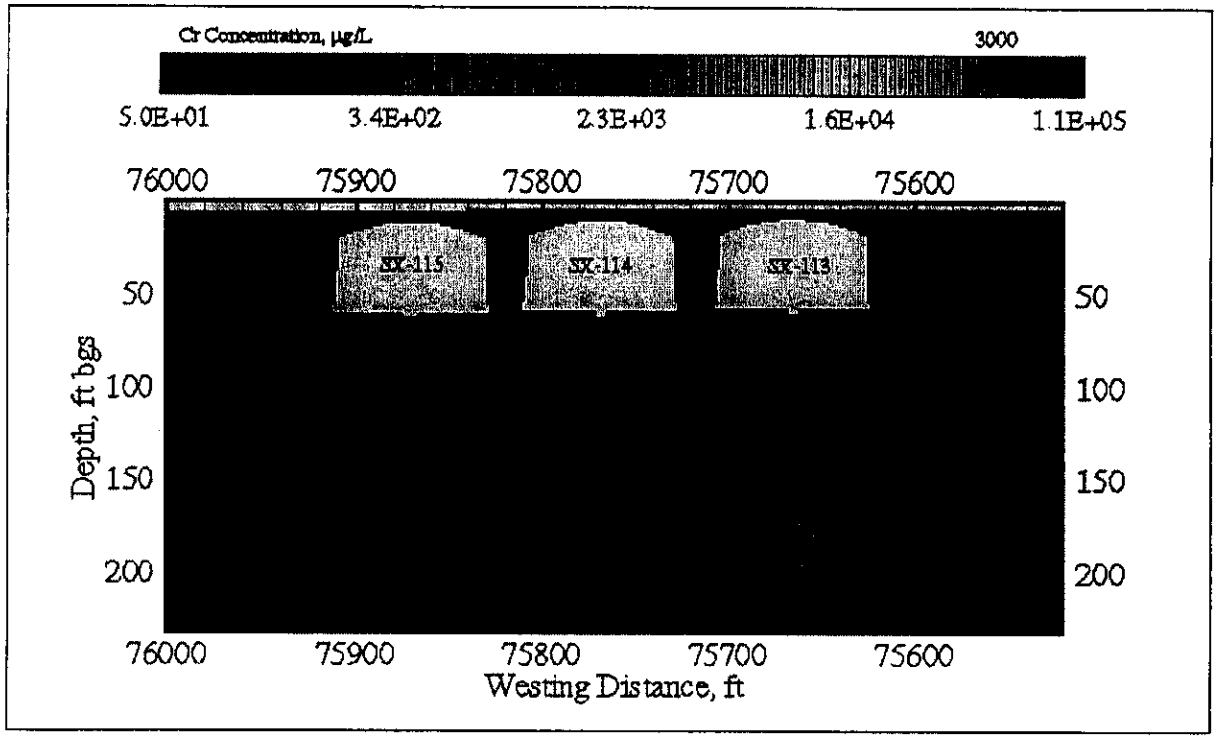


Figure E4.36. NO_3 Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

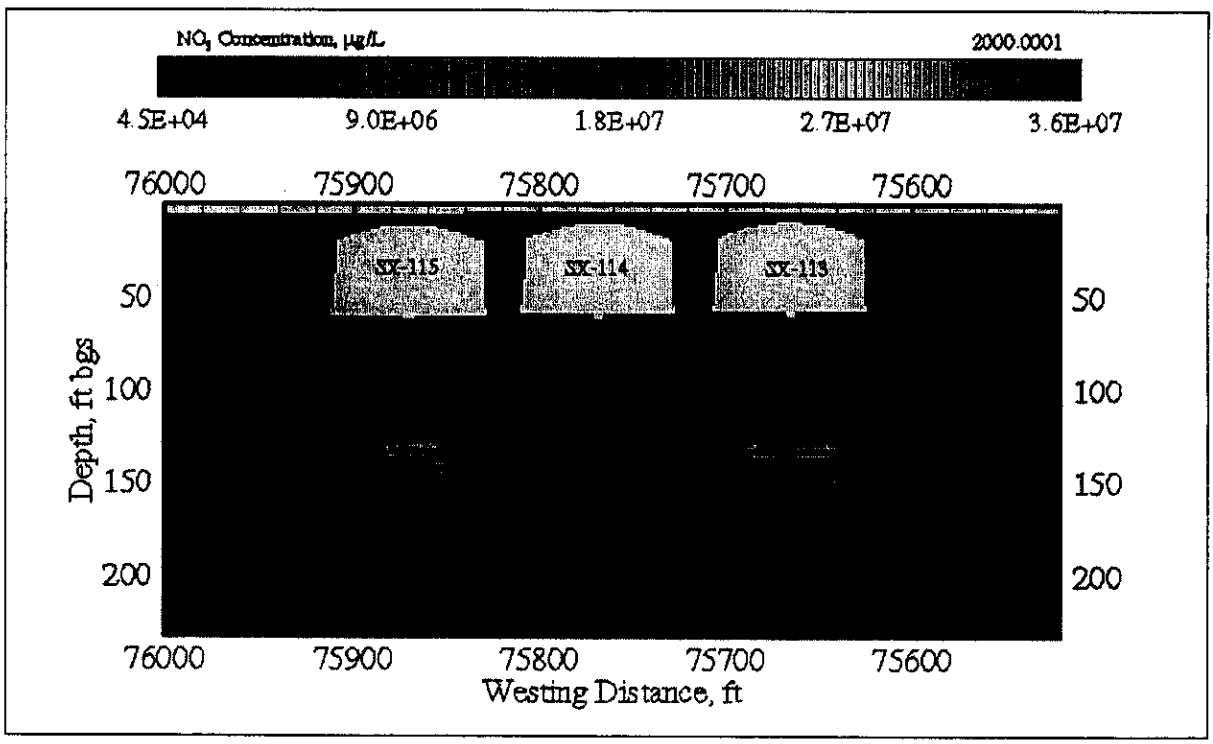


Figure E4.37. NO_3 Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

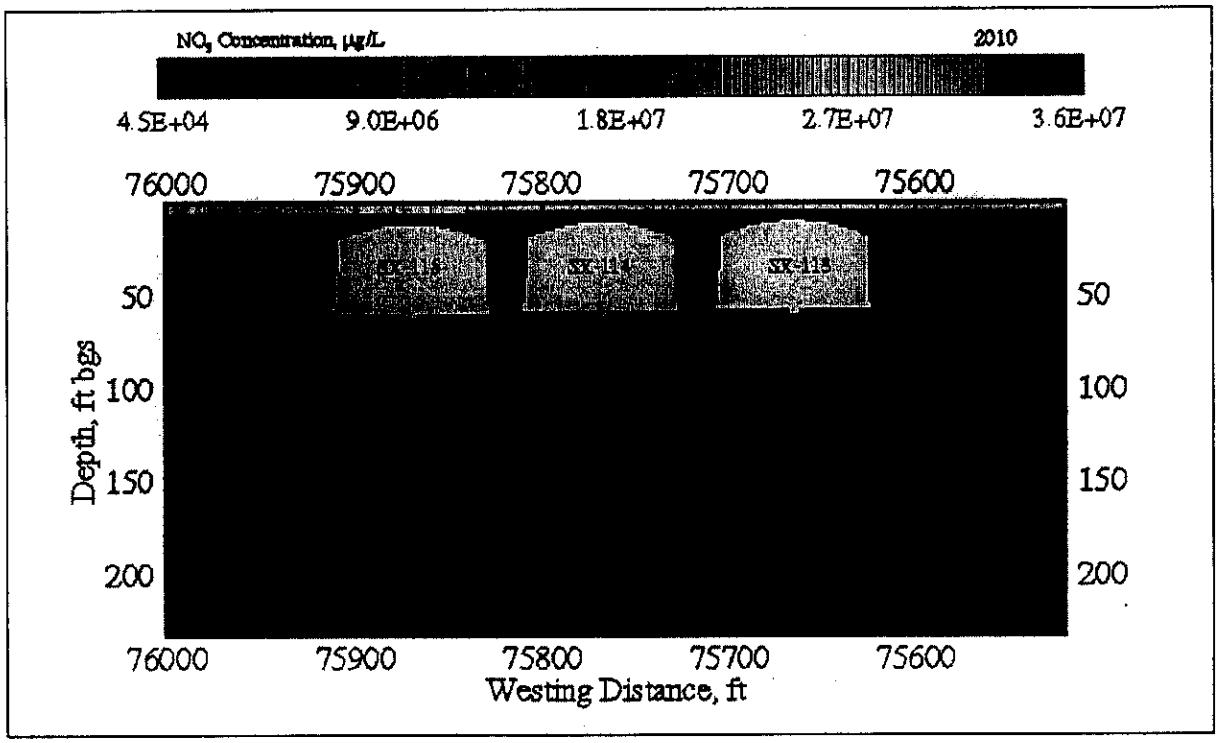


Figure E4.38. NO_3 Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

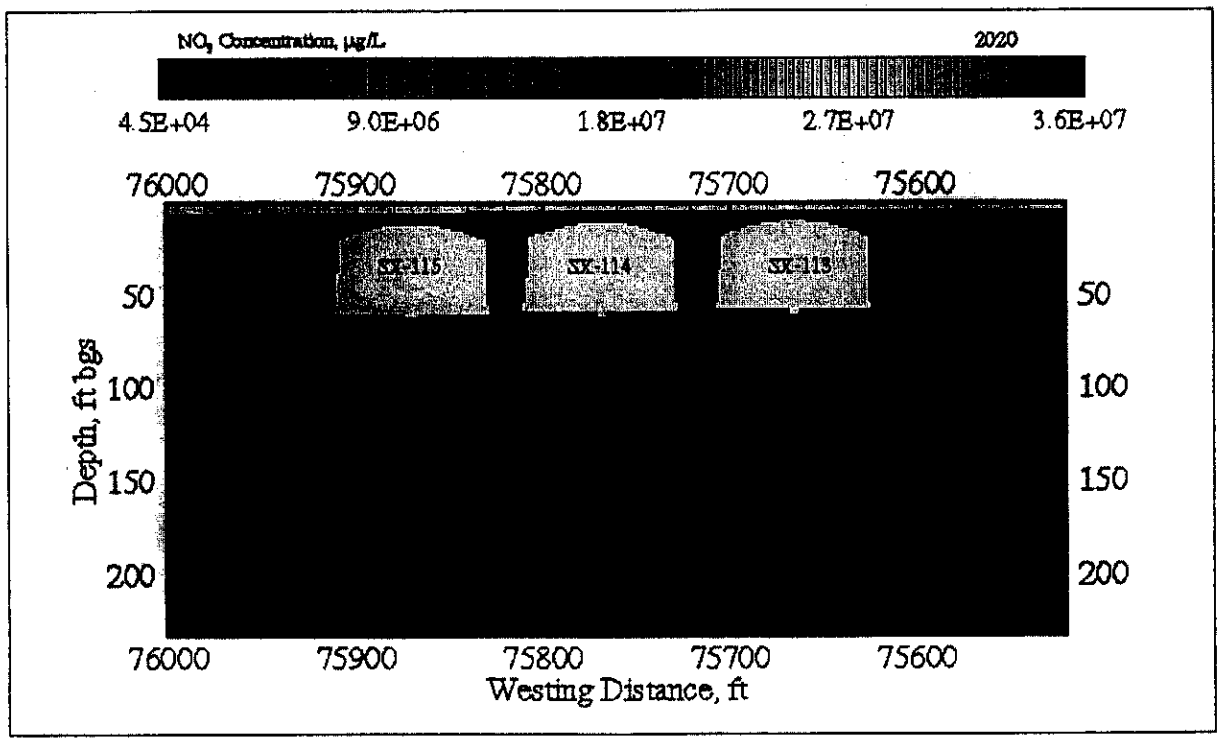


Figure E4.39. NO_3 Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

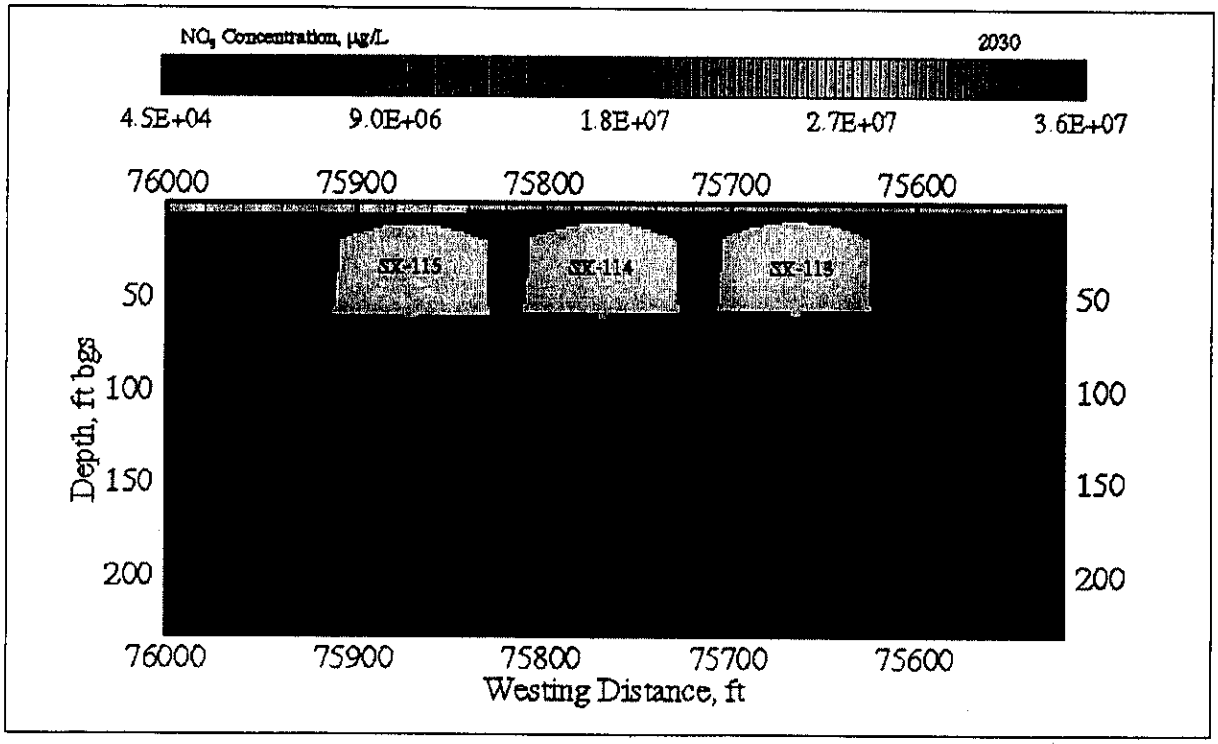


Figure E4.40. NO_3 Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

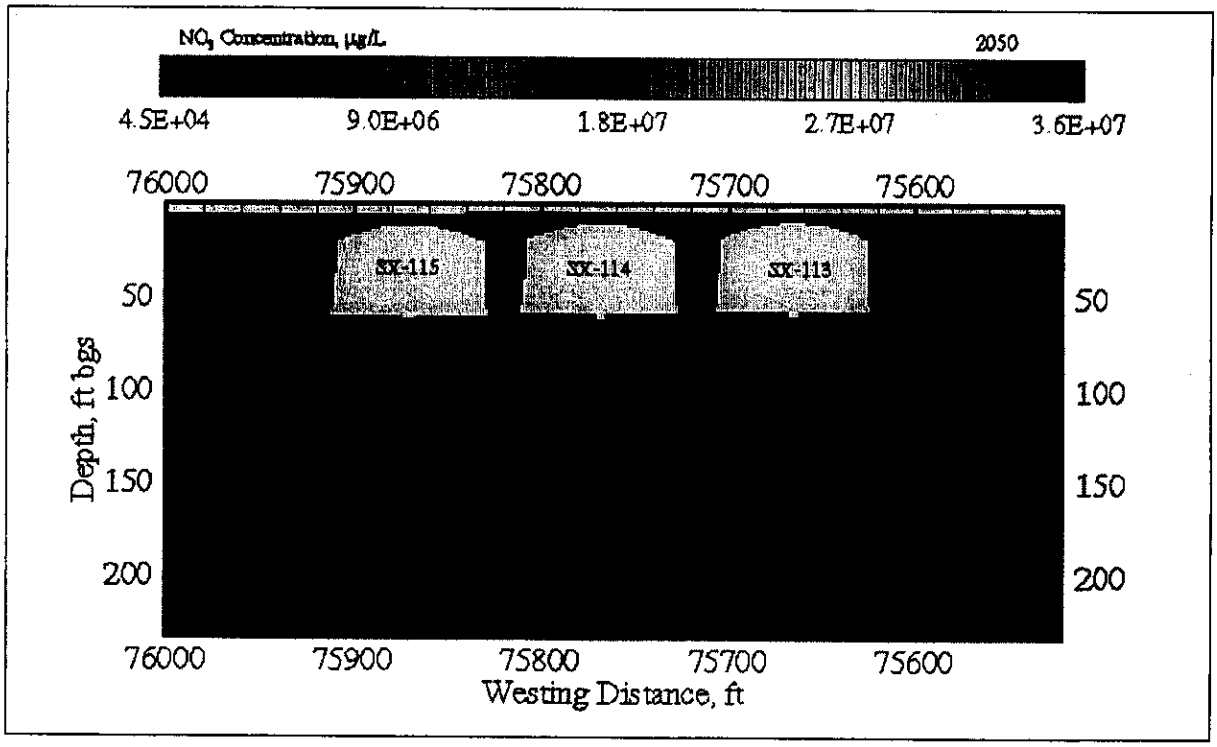


Figure E4.41. NO_3 Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

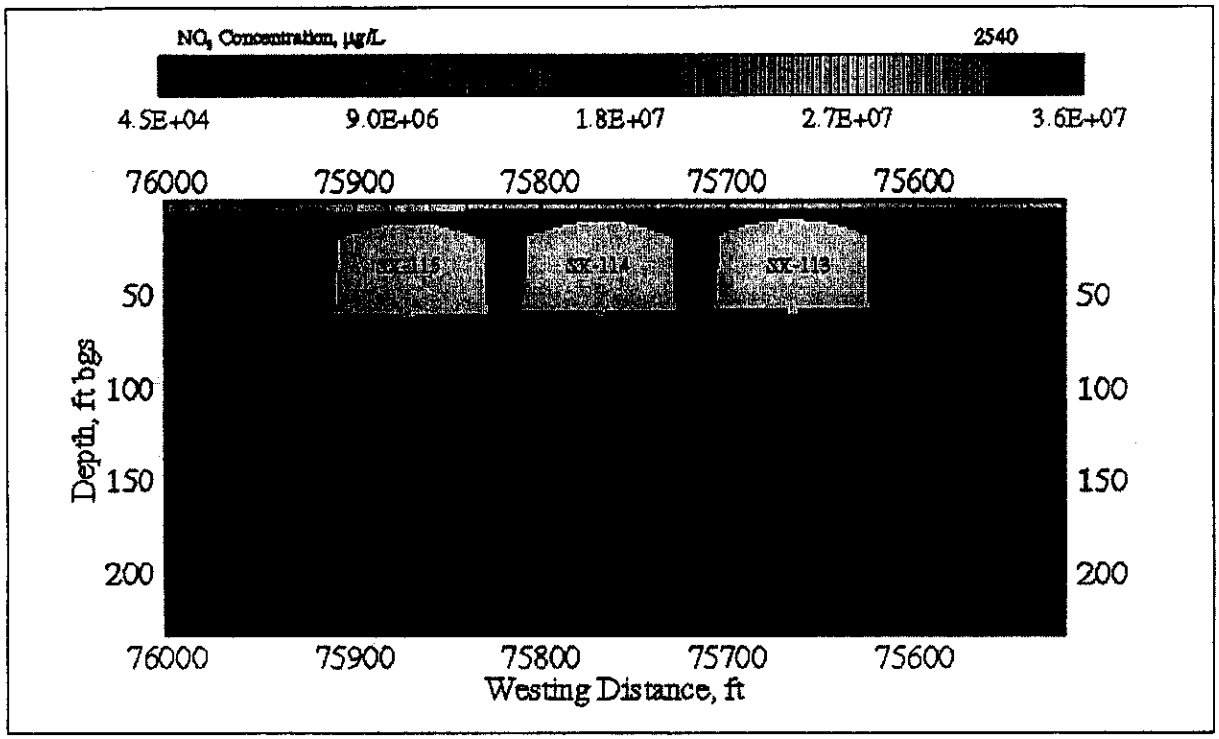


Figure E4.42. NO_3 Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section SX-FF' (SX-113, -114, -115)

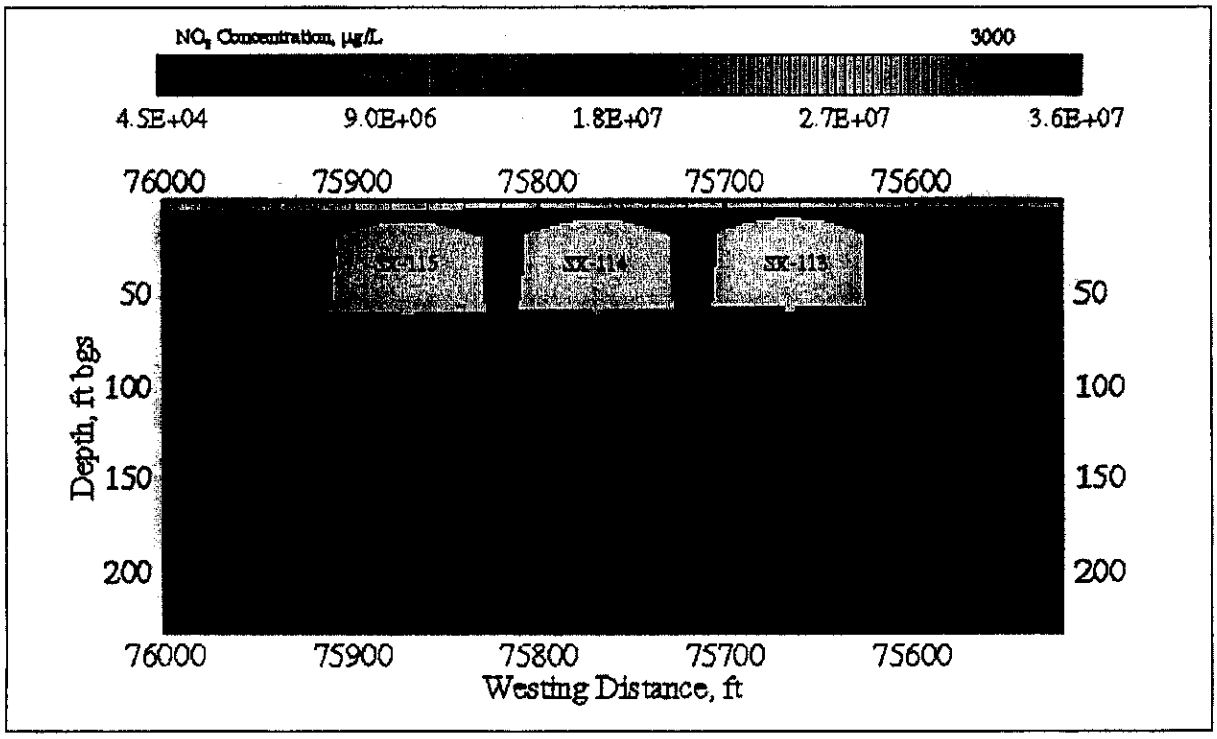


Figure E4.43. Tc-99 Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

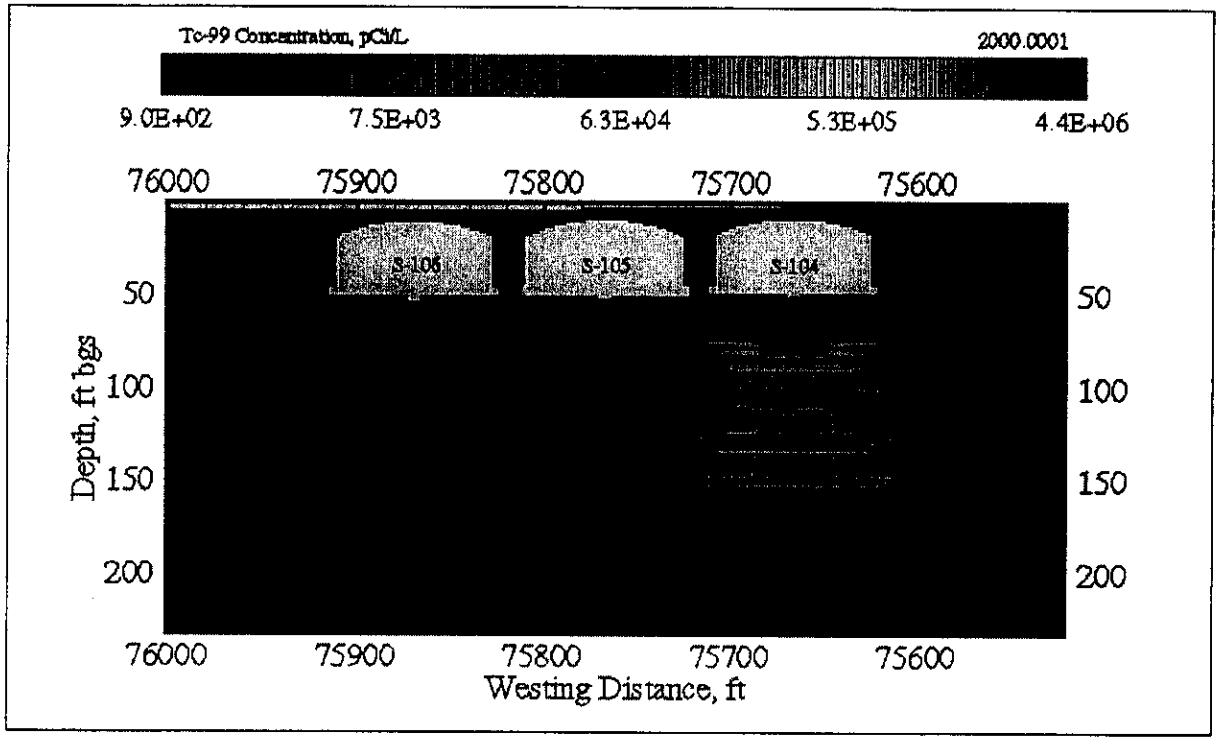


Figure E4.44. Tc-99 Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

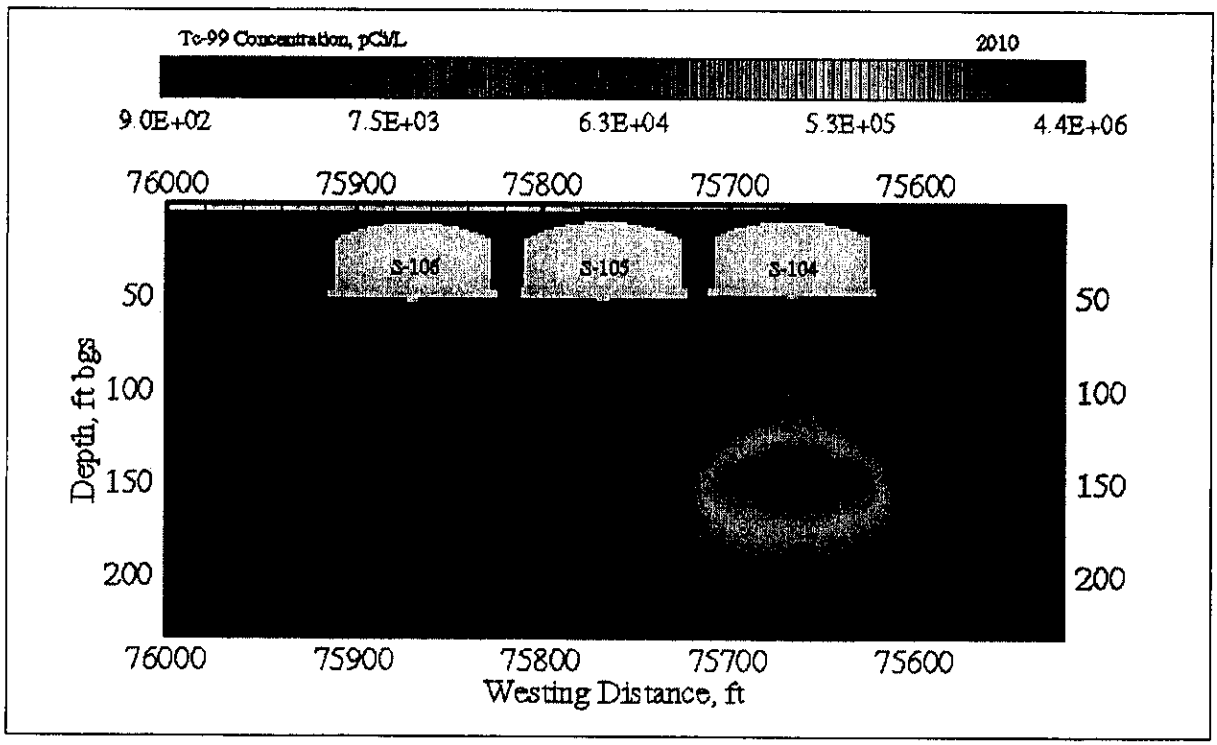


Figure E4.45. Tc-99 Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

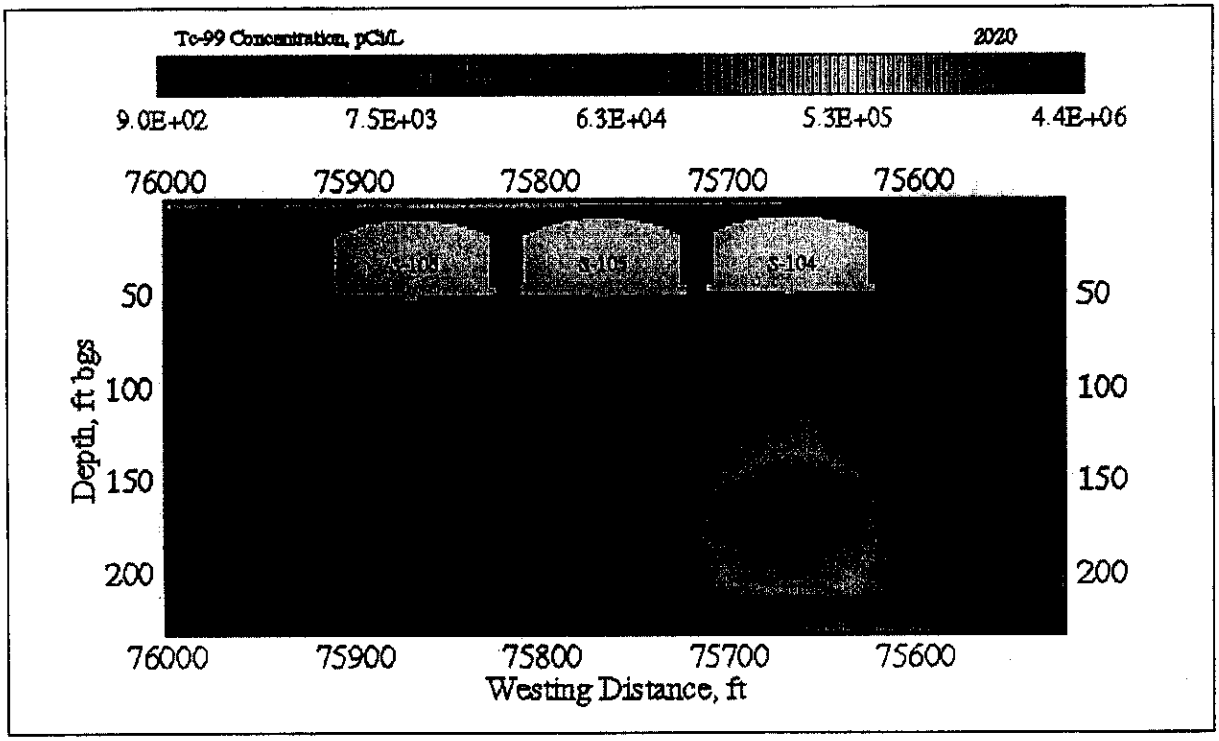


Figure E4.46. Tc-99 Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

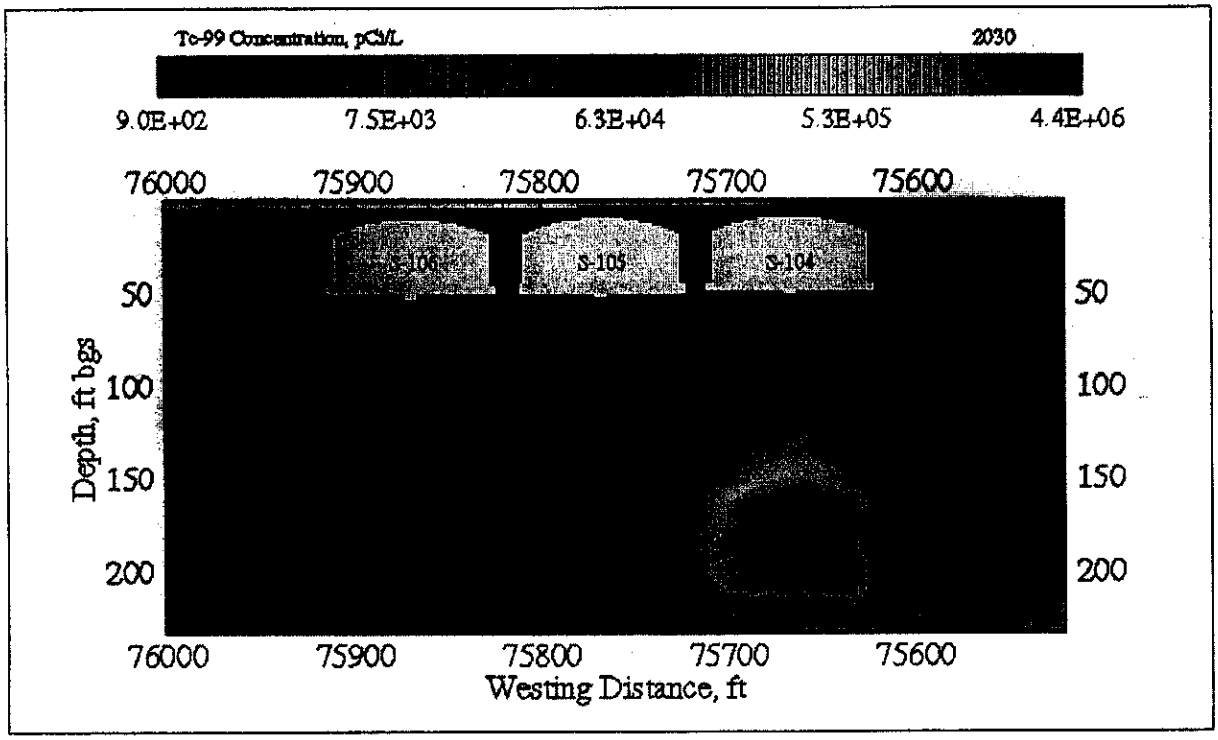


Figure E4.47. Tc-99 Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

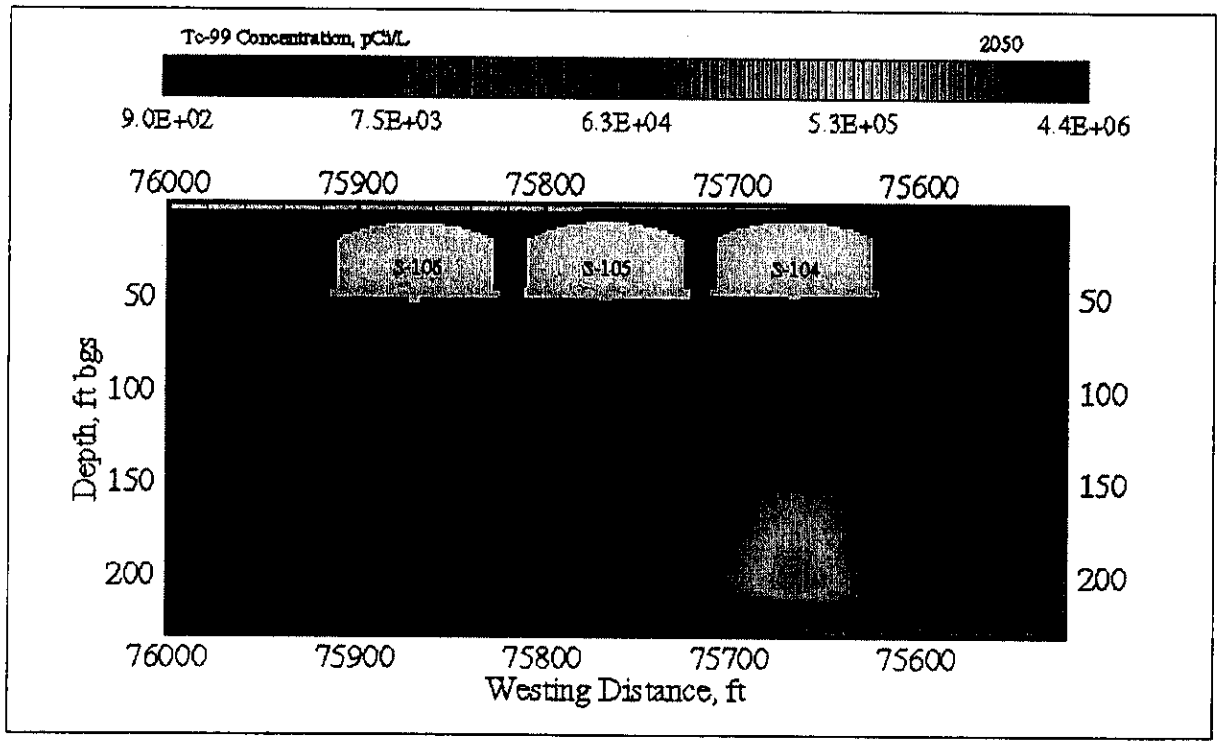


Figure E4.48. Tc-99 Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

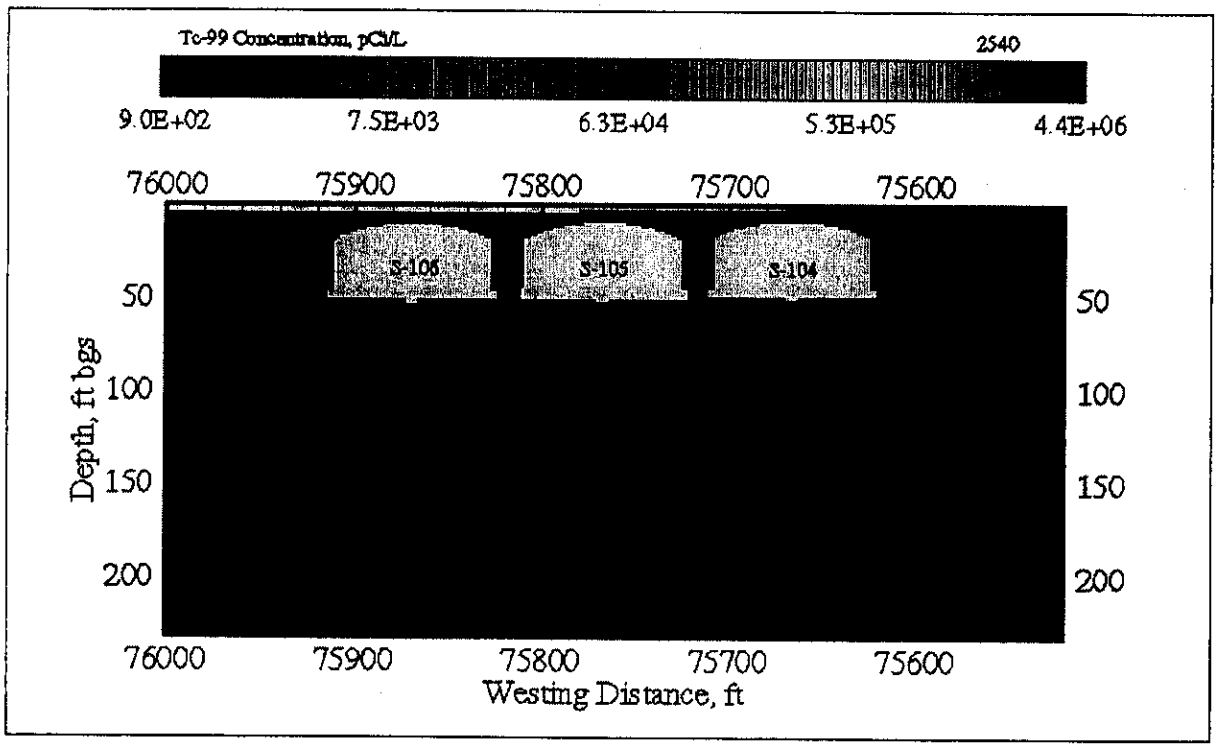


Figure E4.49. Tc-99 Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

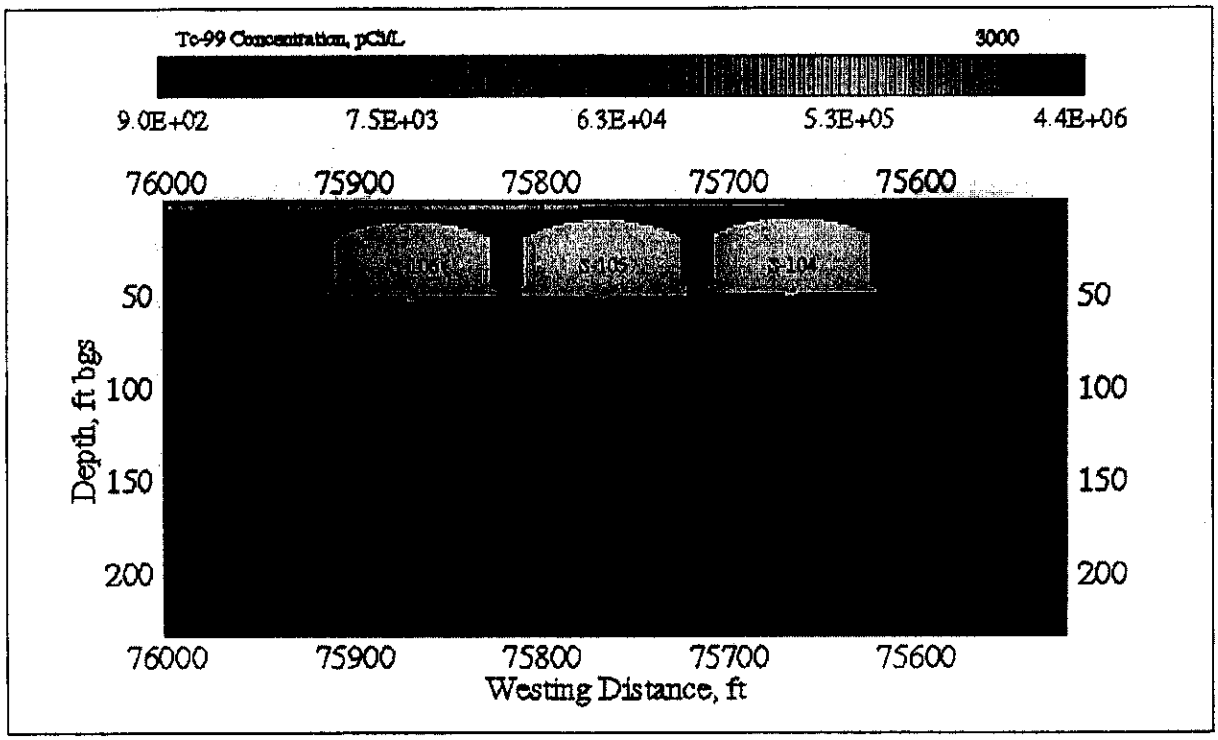


Figure E4.50. Cr Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

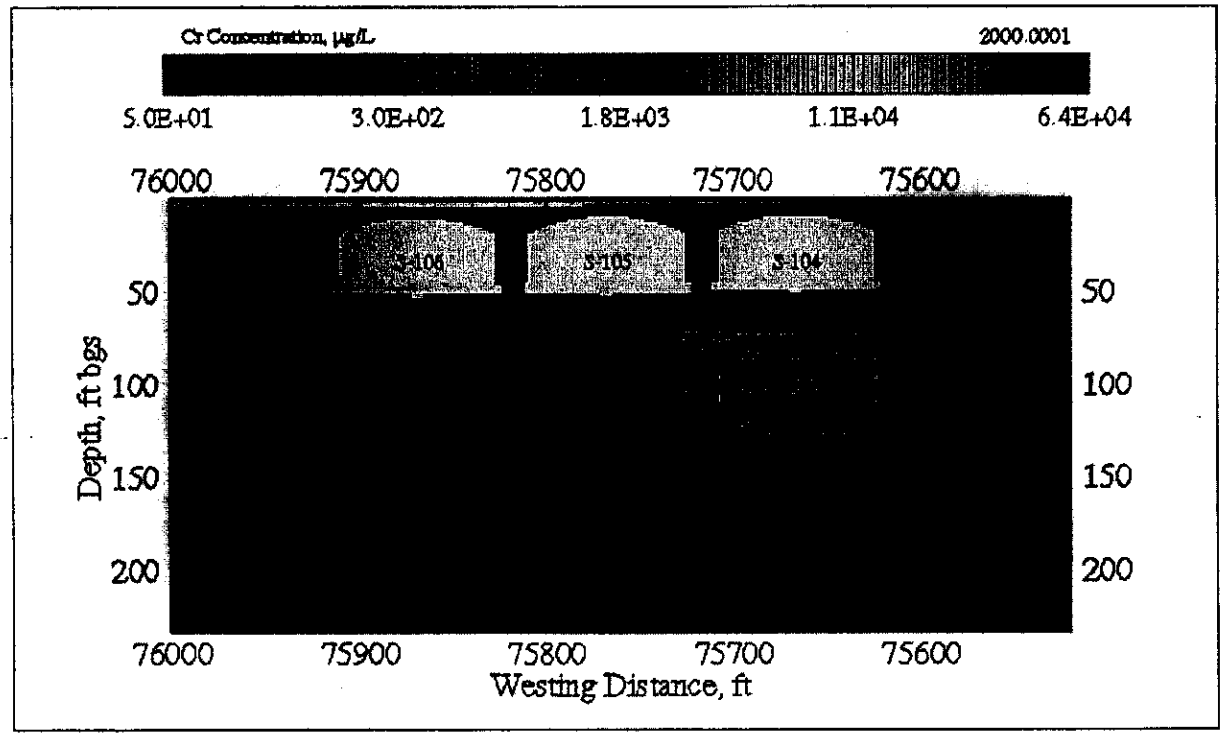


Figure E4.51. Cr Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

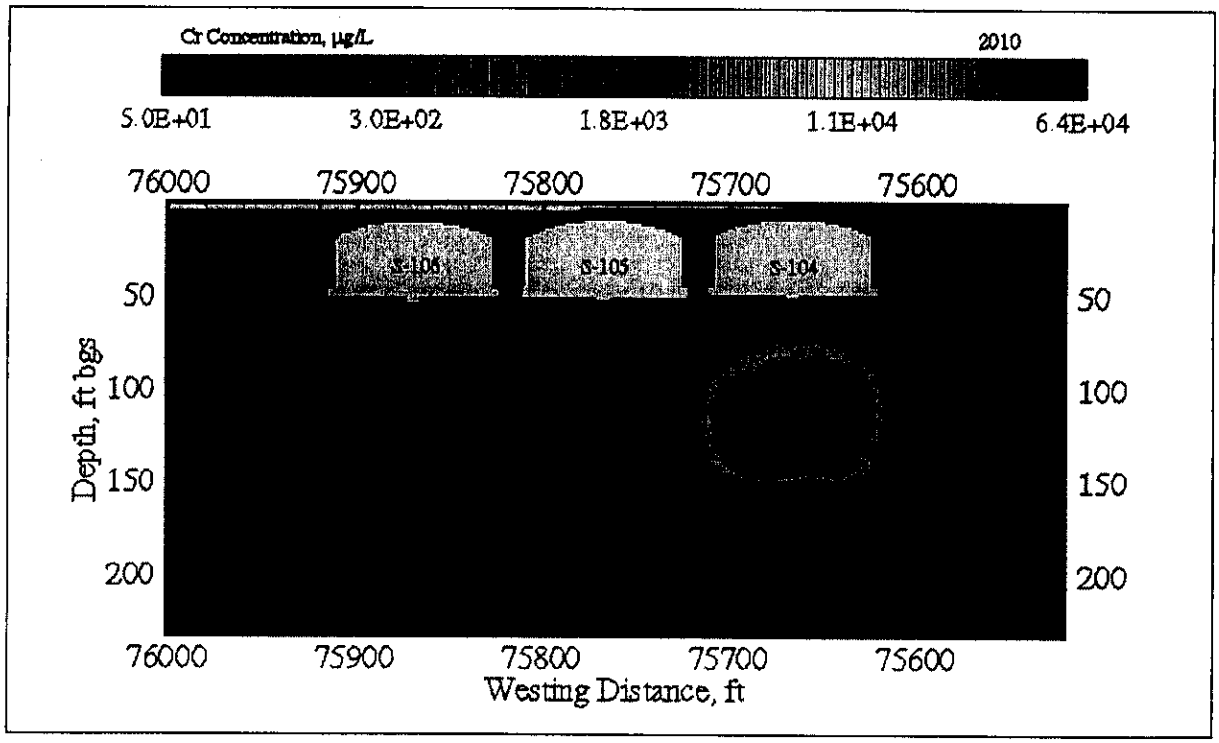


Figure E4.52. Cr Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

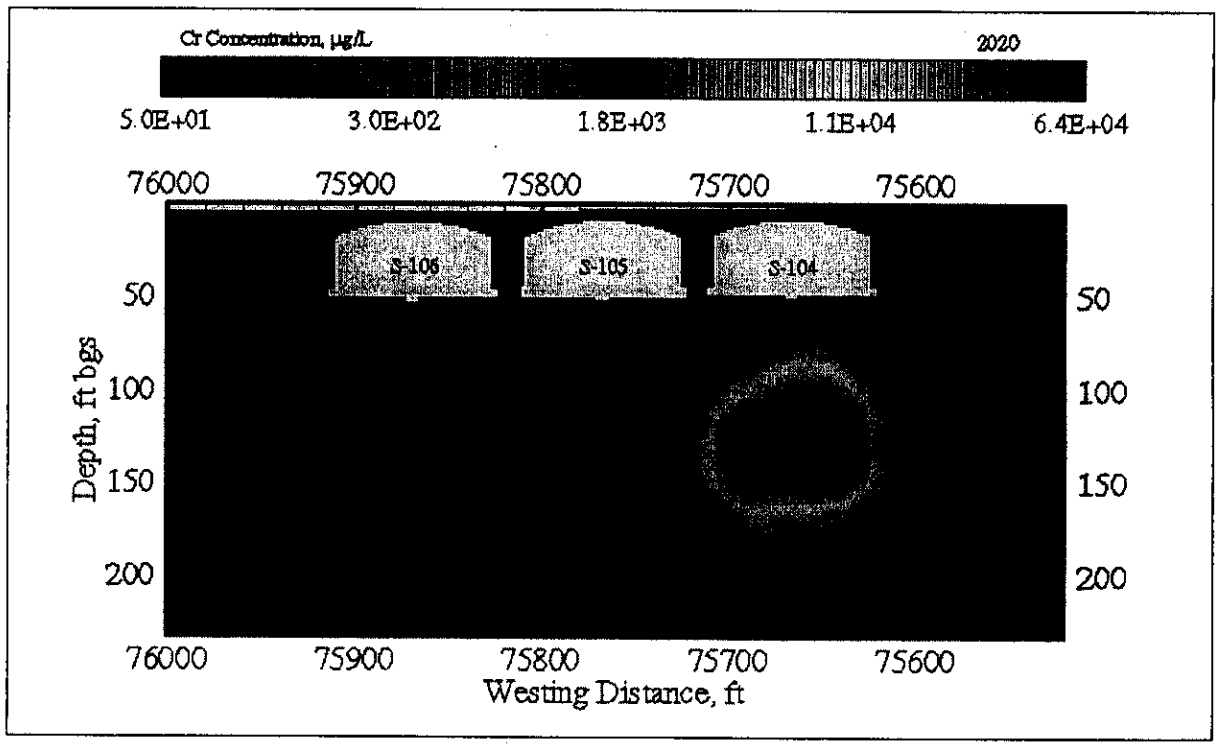


Figure E4.53. Cr Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

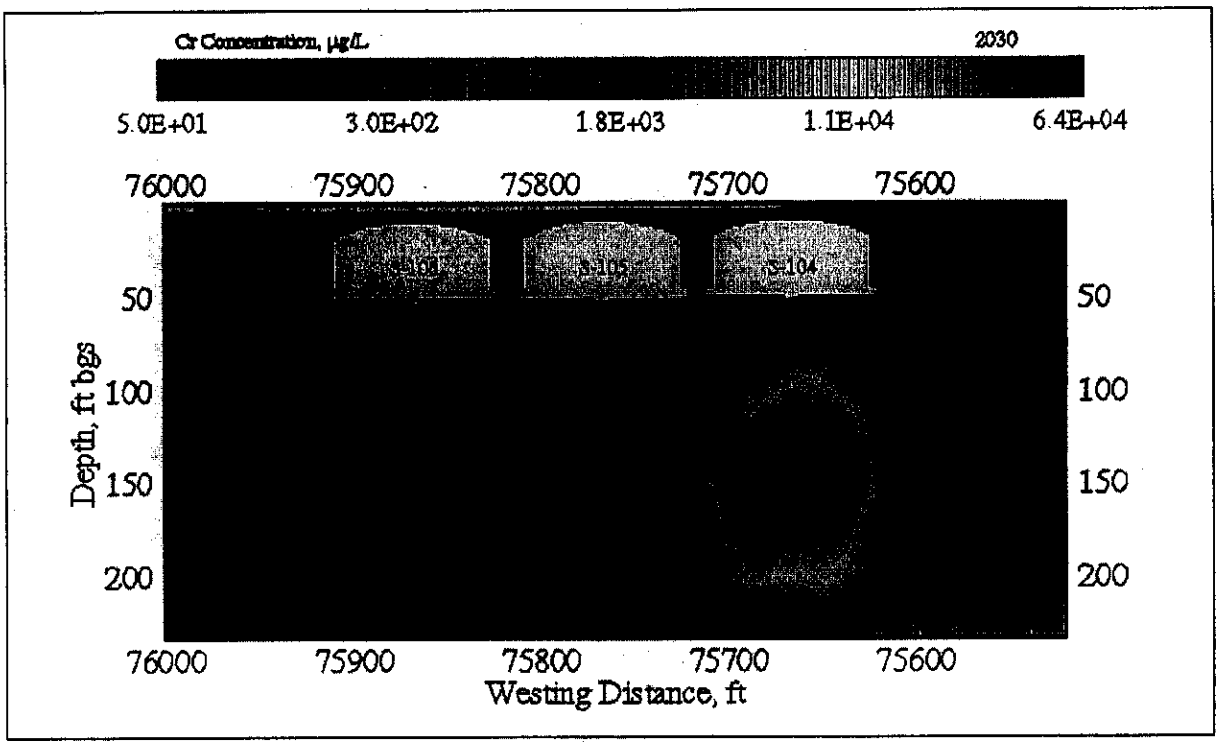


Figure E4.54. Cr Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

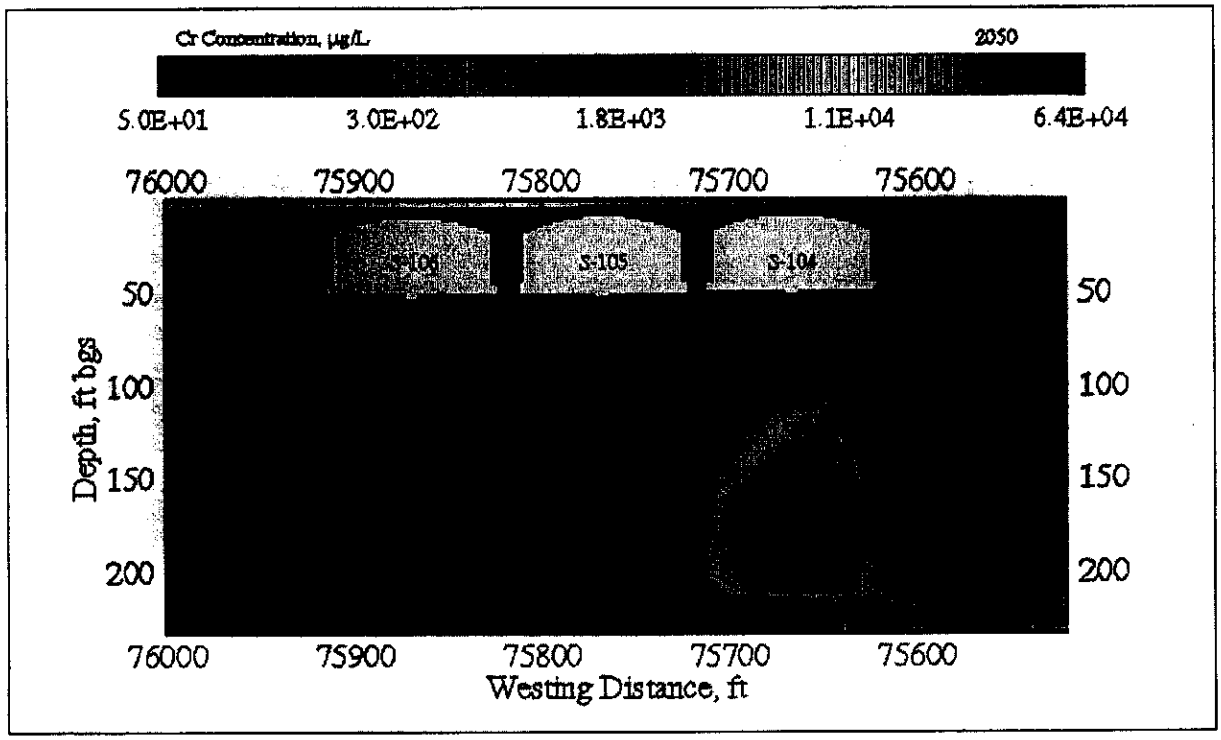


Figure E4.55. Cr Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

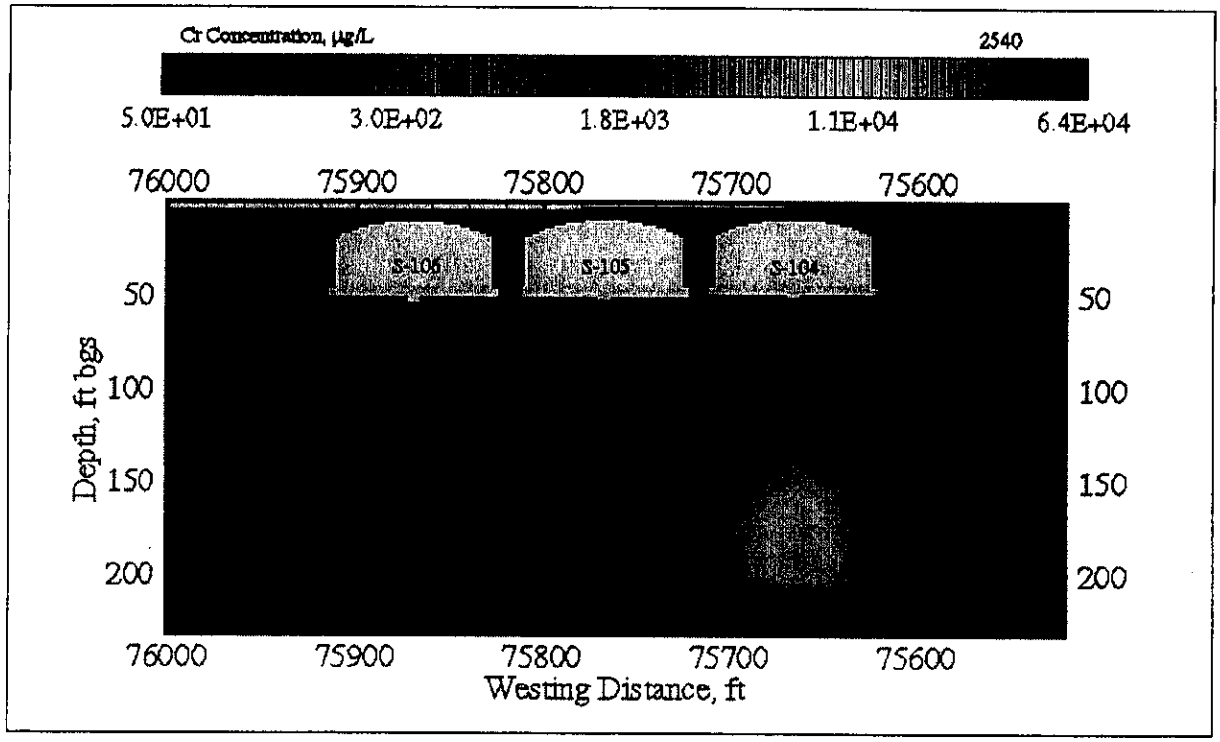


Figure E4.56. Cr Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

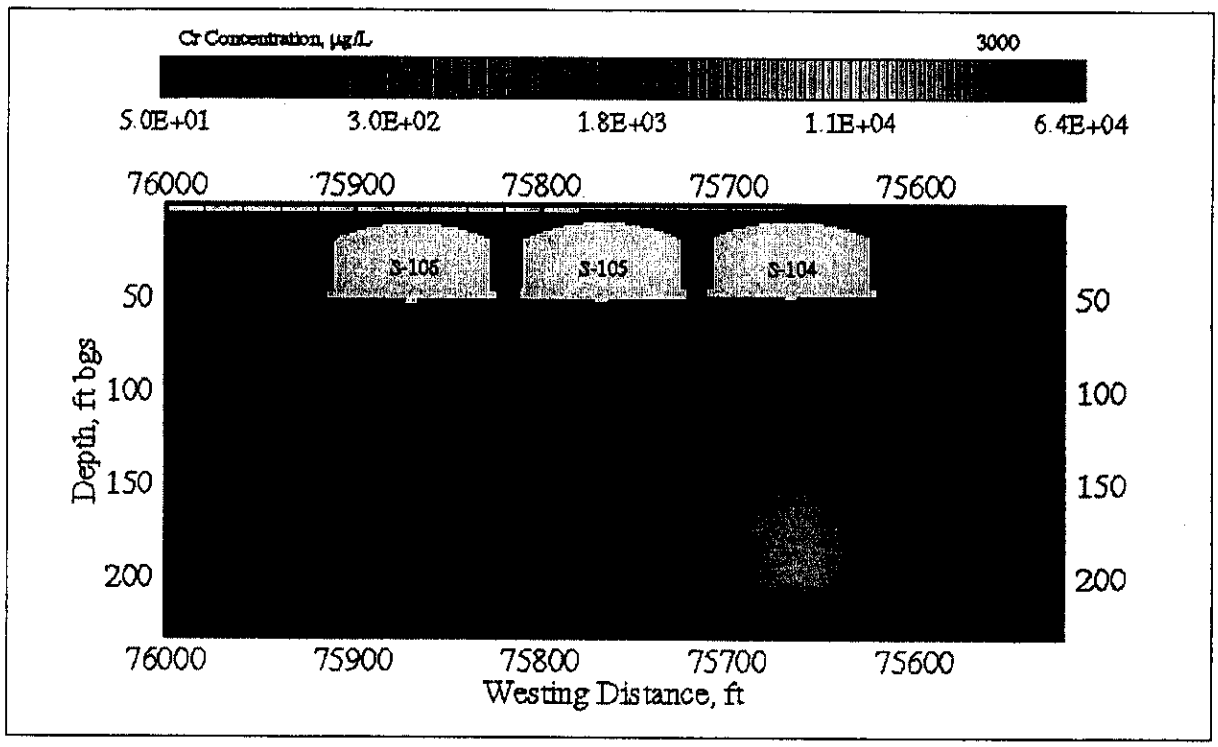


Figure E4.57. NO_3 Aqueous Concentration at 2000.0001 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

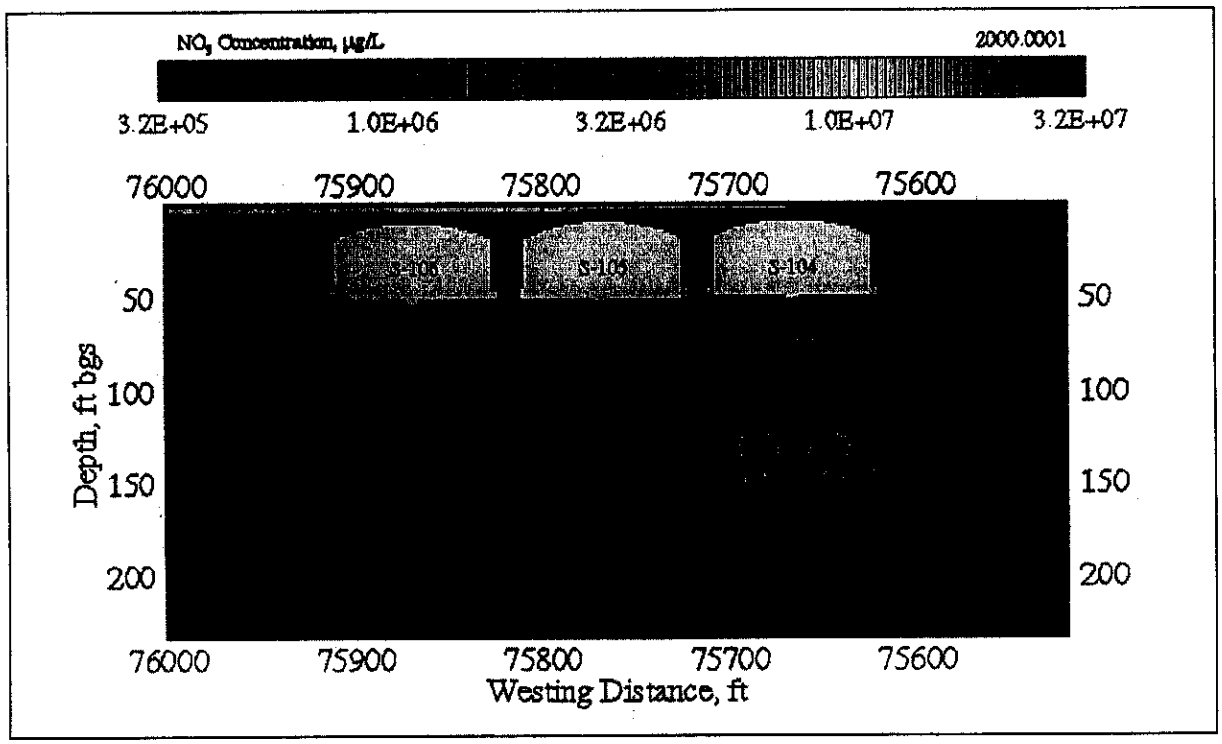


Figure E4.58. NO_3 Aqueous Concentration at 2010 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

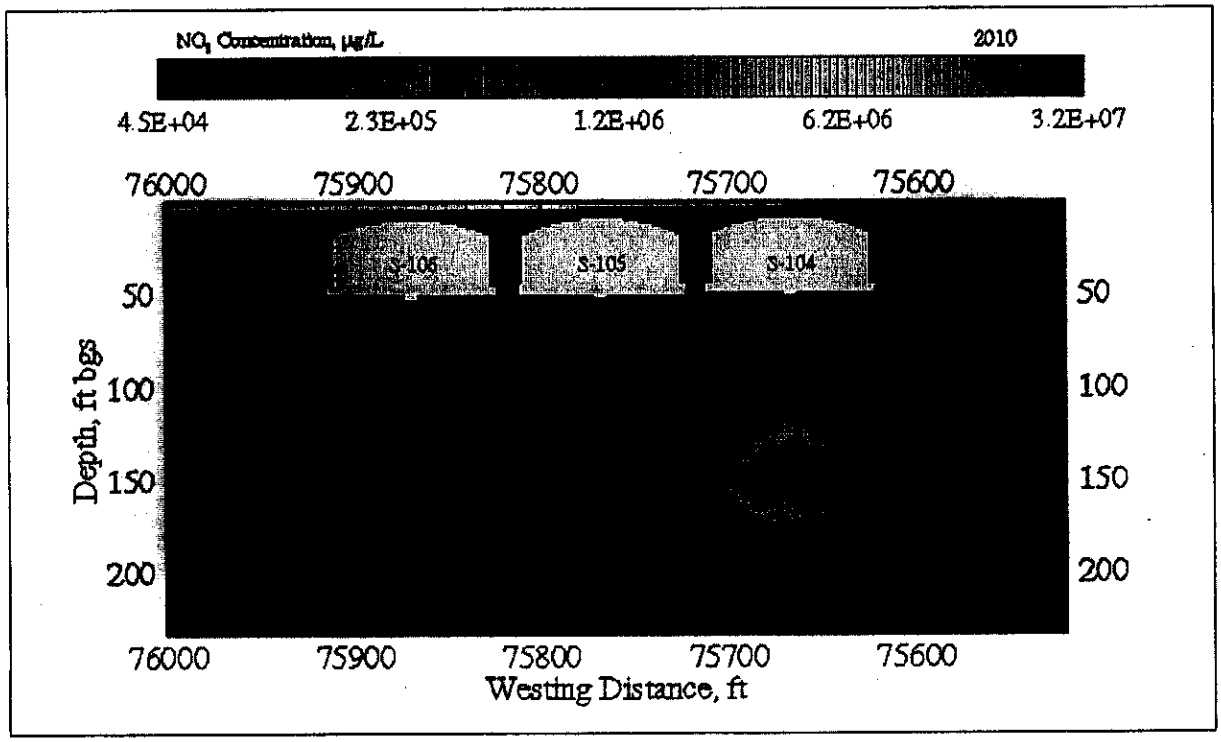


Figure E4.59. NO_3 Aqueous Concentration at 2020 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

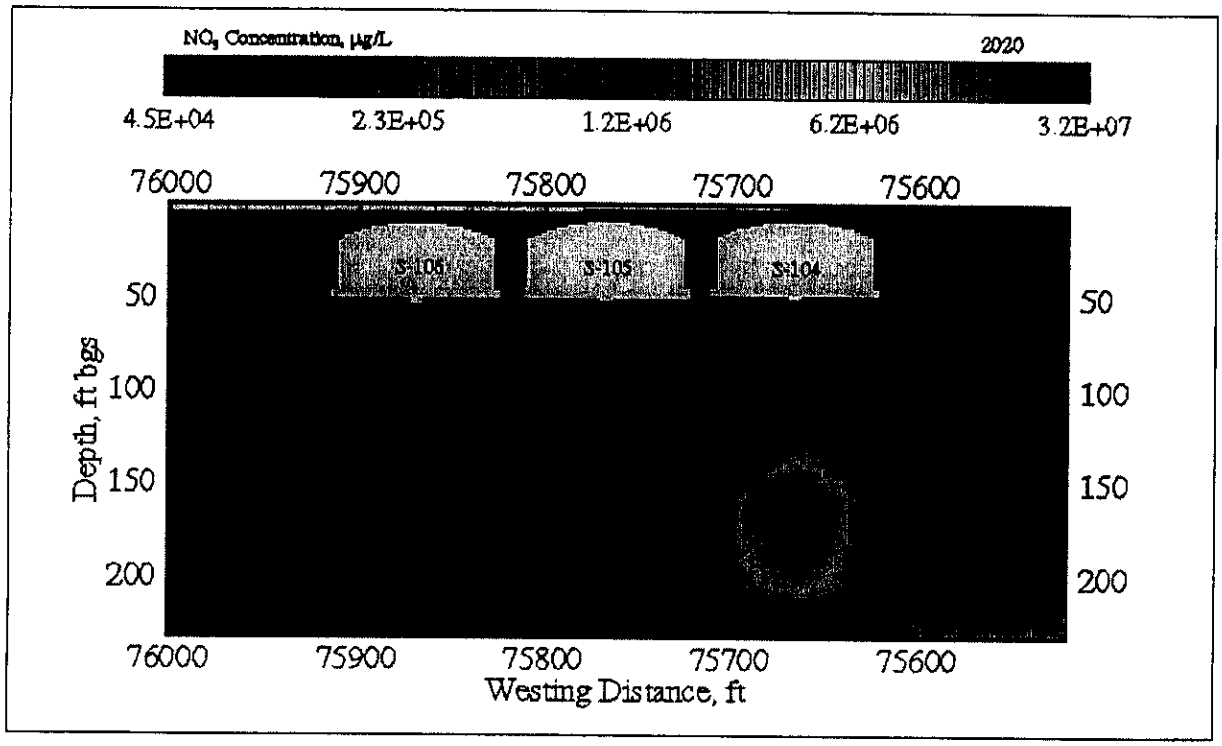


Figure E4.60. NO_3 Aqueous Concentration at 2030 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

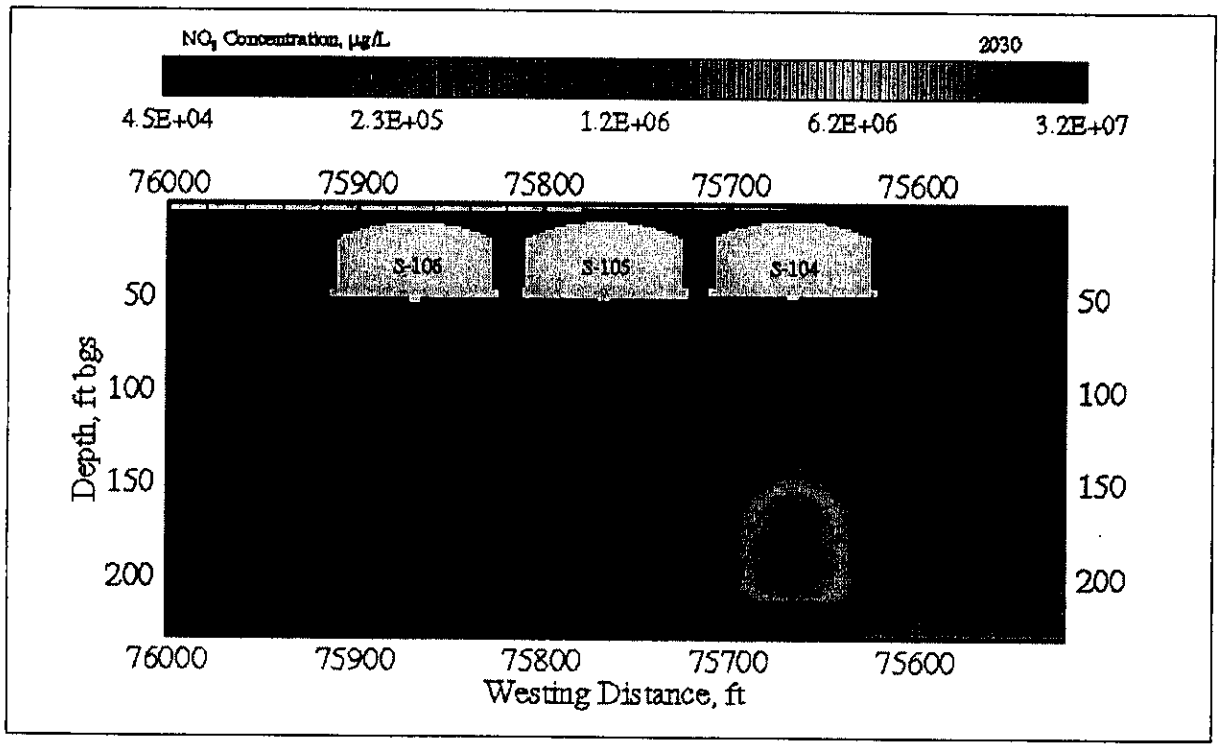


Figure E4.61. NO_3 Aqueous Concentration at 2050 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

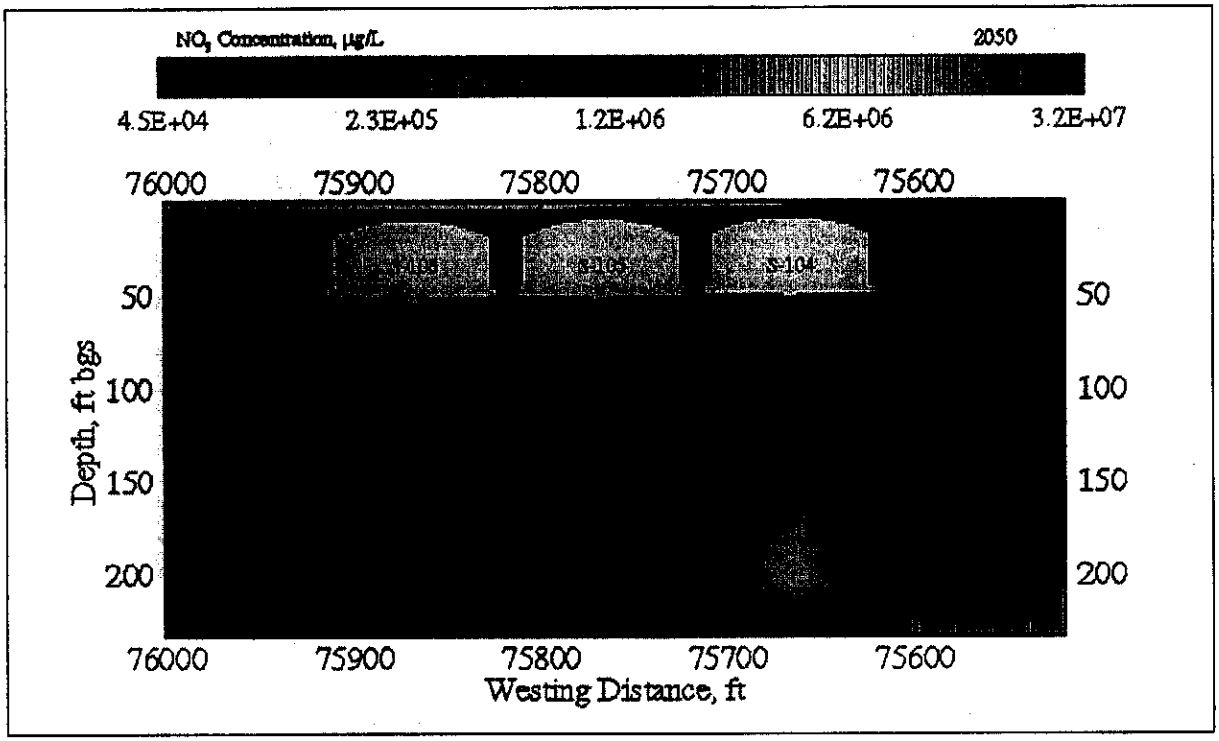


Figure E4.62. NO_3 Aqueous Concentration at 2540 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)

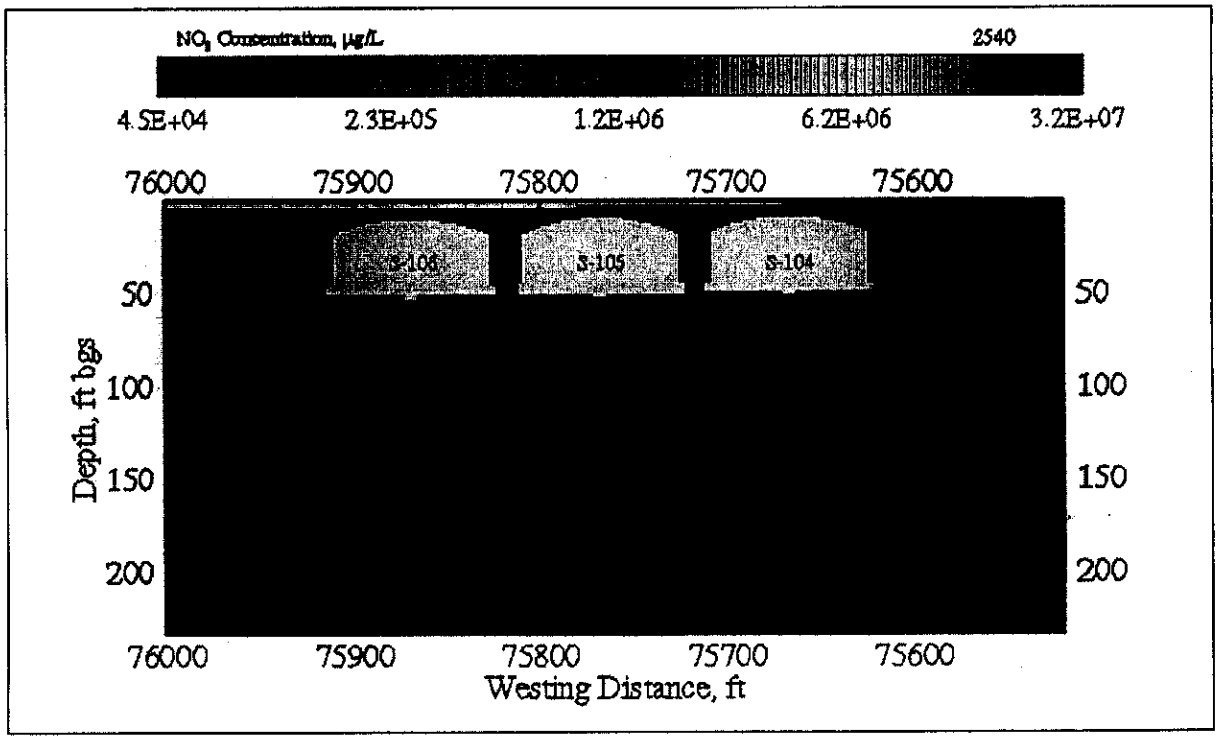
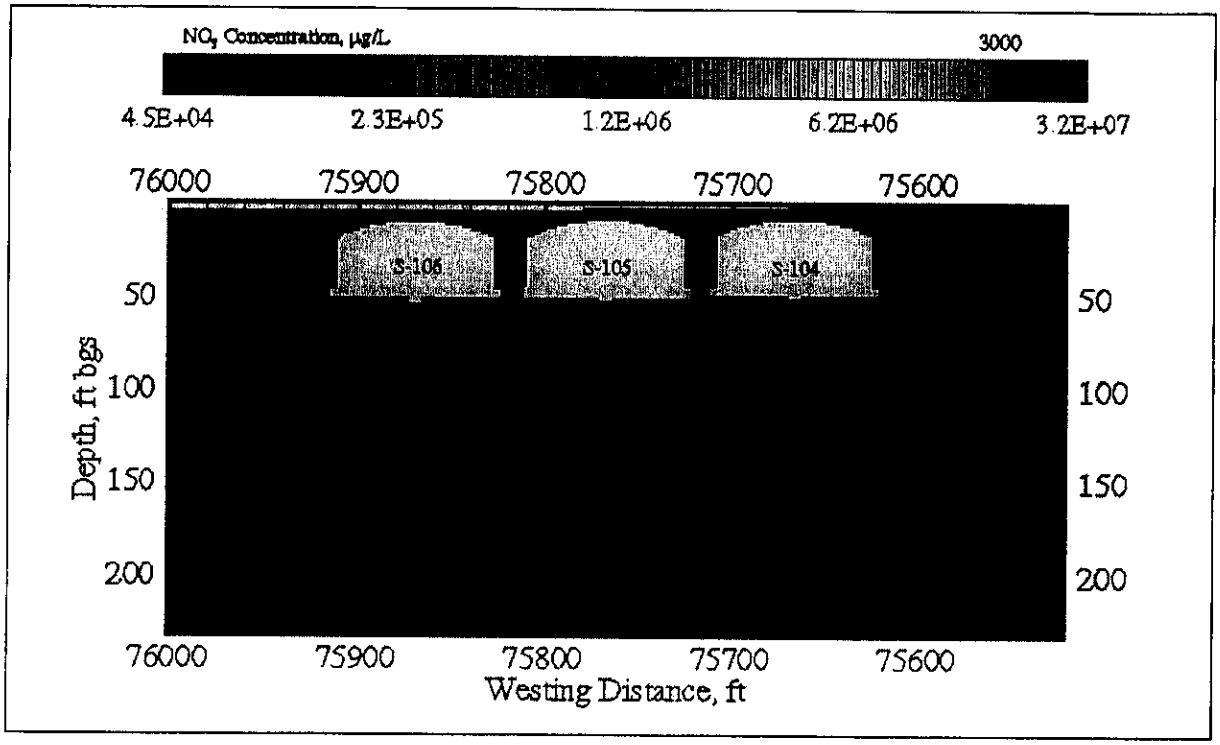


Figure E4.63. NO_3 Aqueous Concentration at 3000 (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106)



ATTACHMENT E5

RECHARGE SENSITIVITY MODELING RESULTS

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FIGURES

E5.1. Tc-99 Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106) for Surface Recharge of 100, 50, 30, and 10 mm/yr E5-1
E5.2. Cr Concentration versus Time at the First Compliance Point (i.e., Waste Management Area S-SX) for Cross-Section S-CC' (S-104, -105, -106) for Surface Recharge of 100, 50, 30, and 10 mm/yr E5-1
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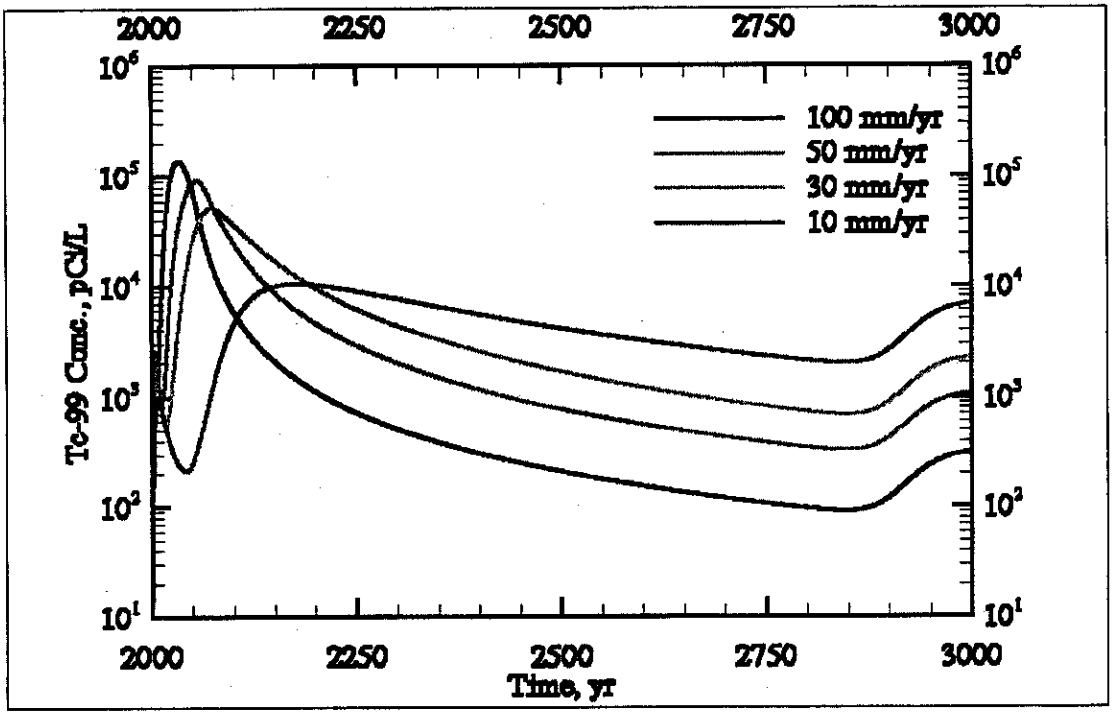

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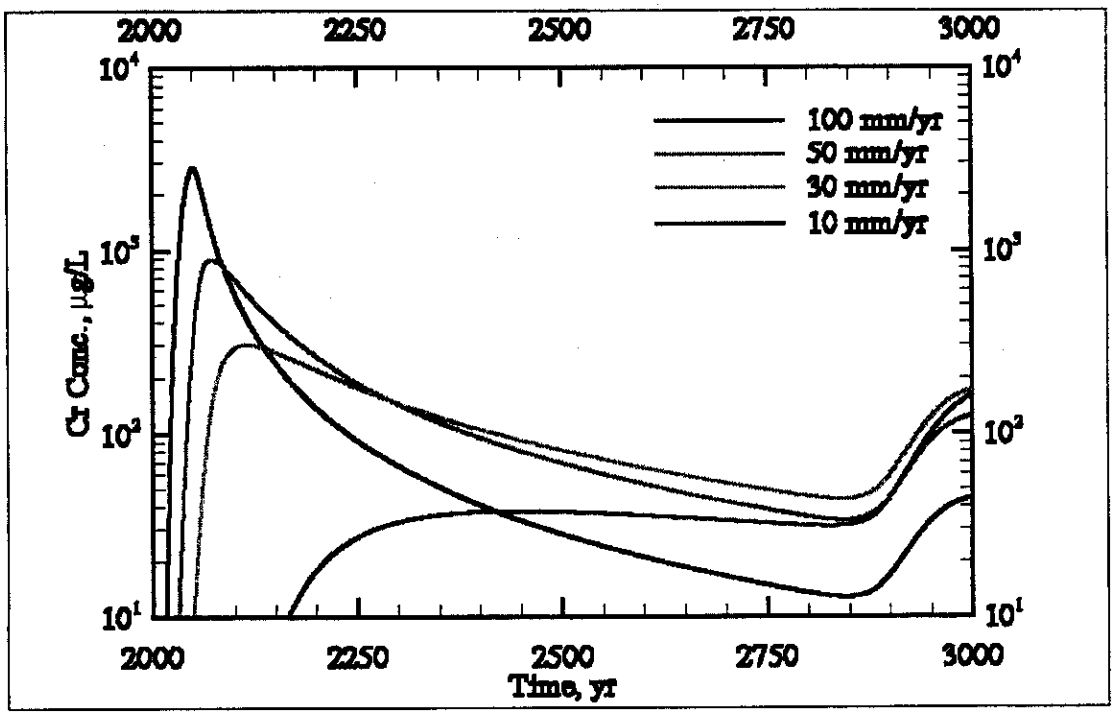

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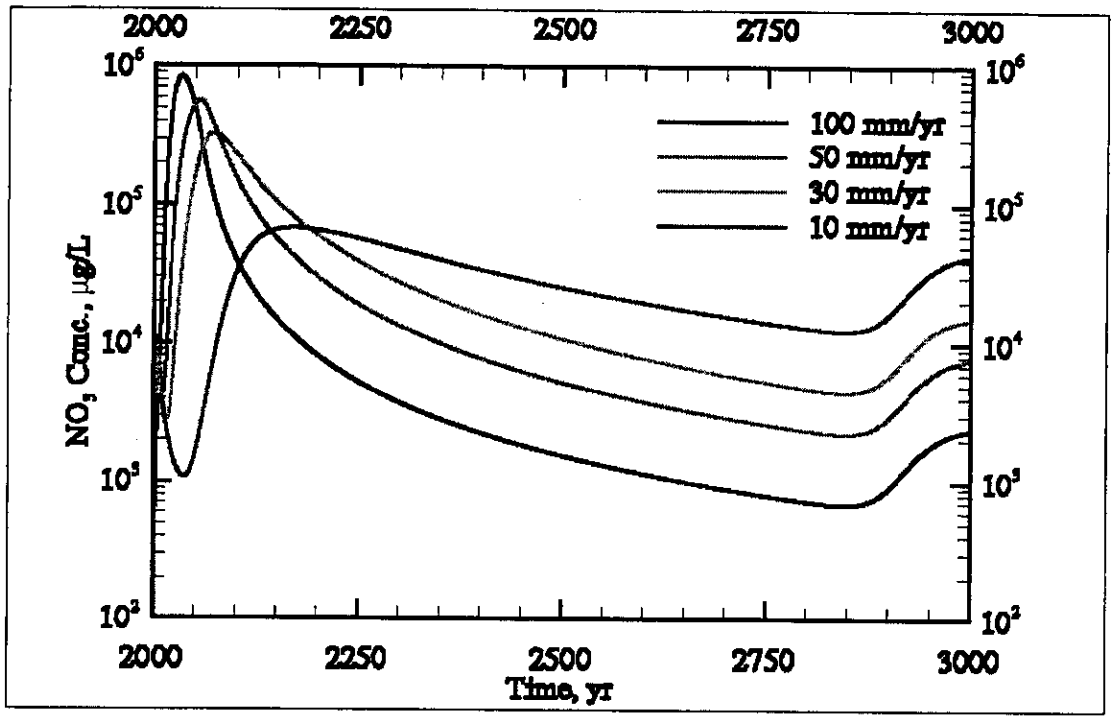

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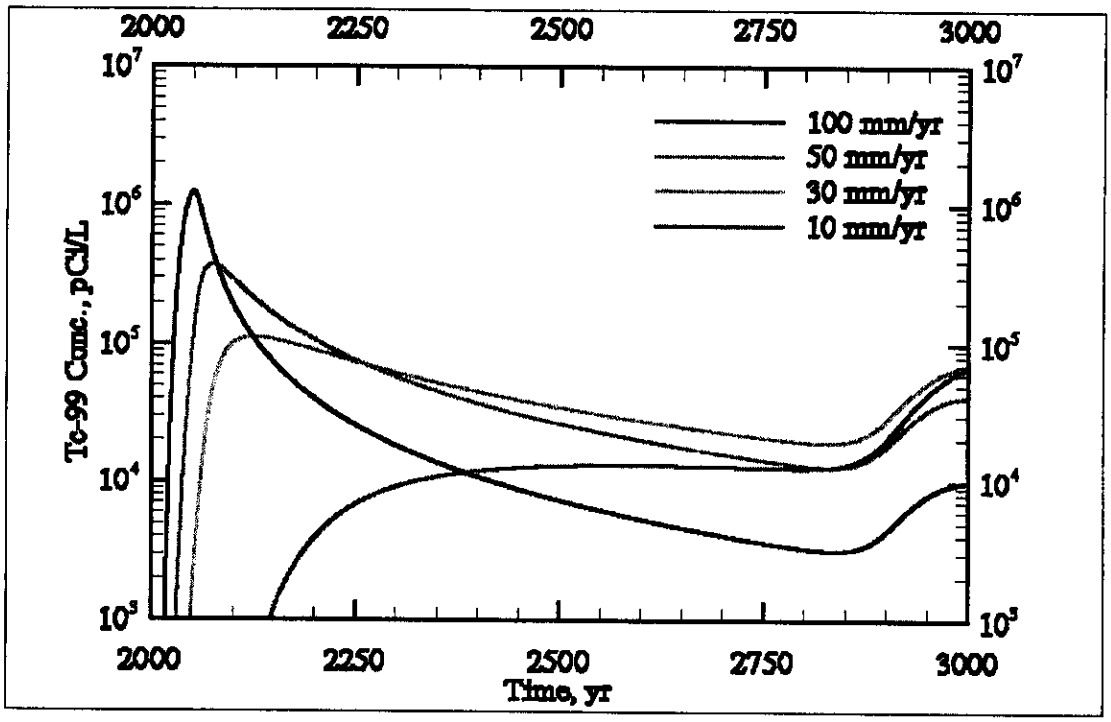

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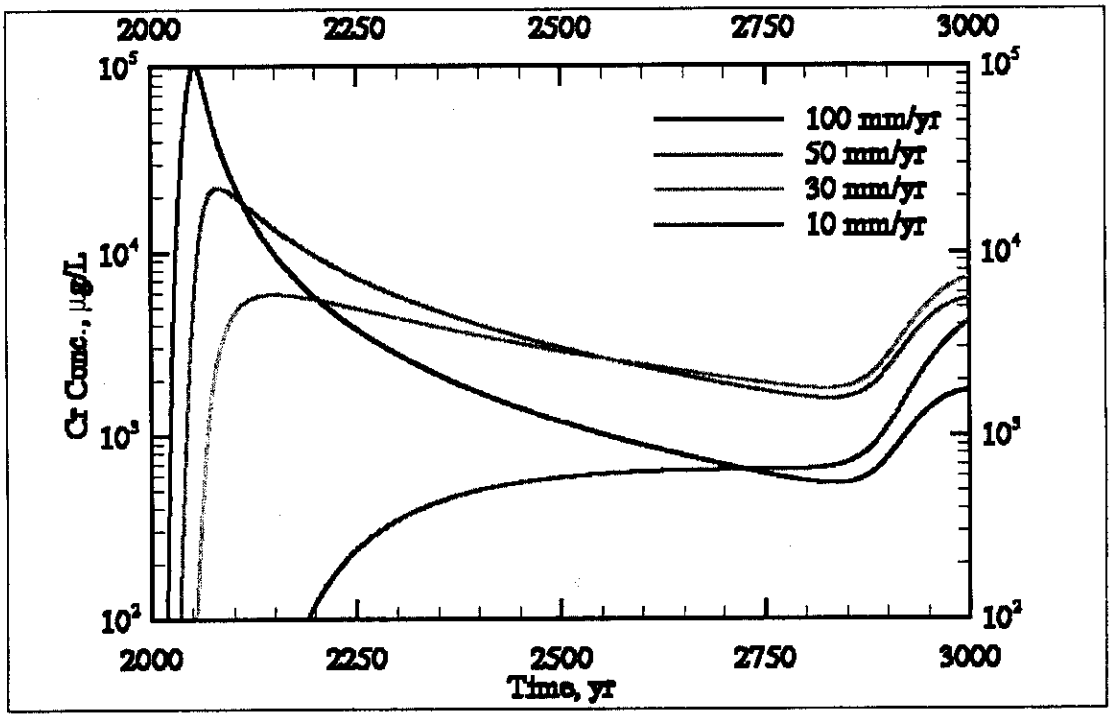

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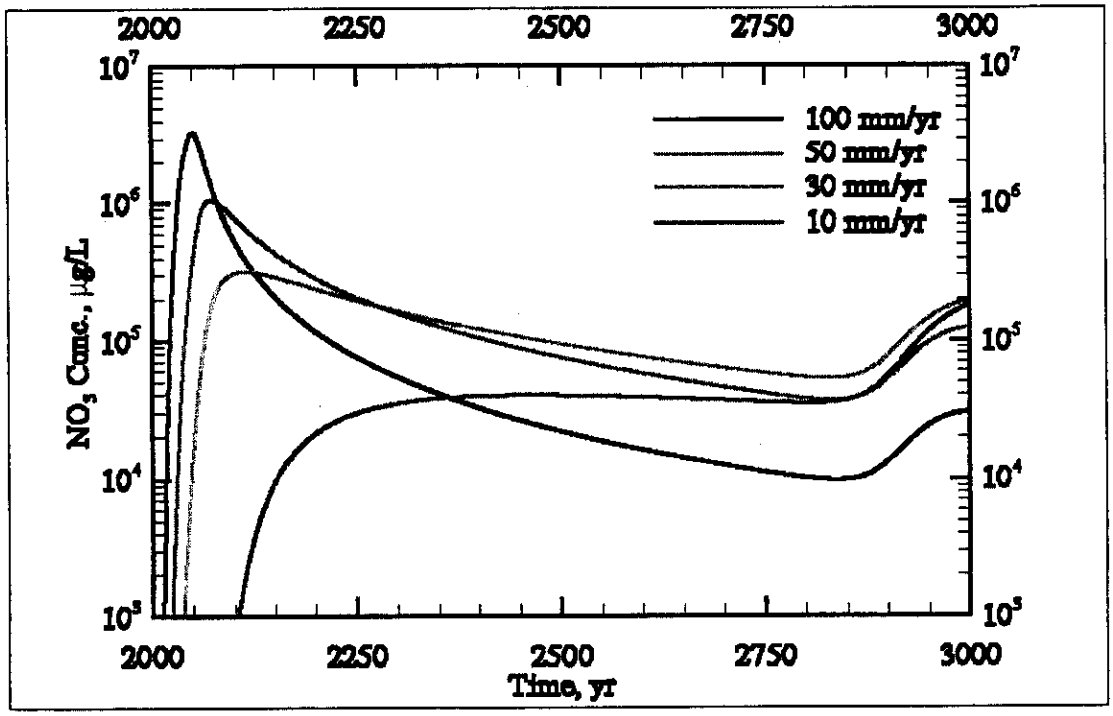

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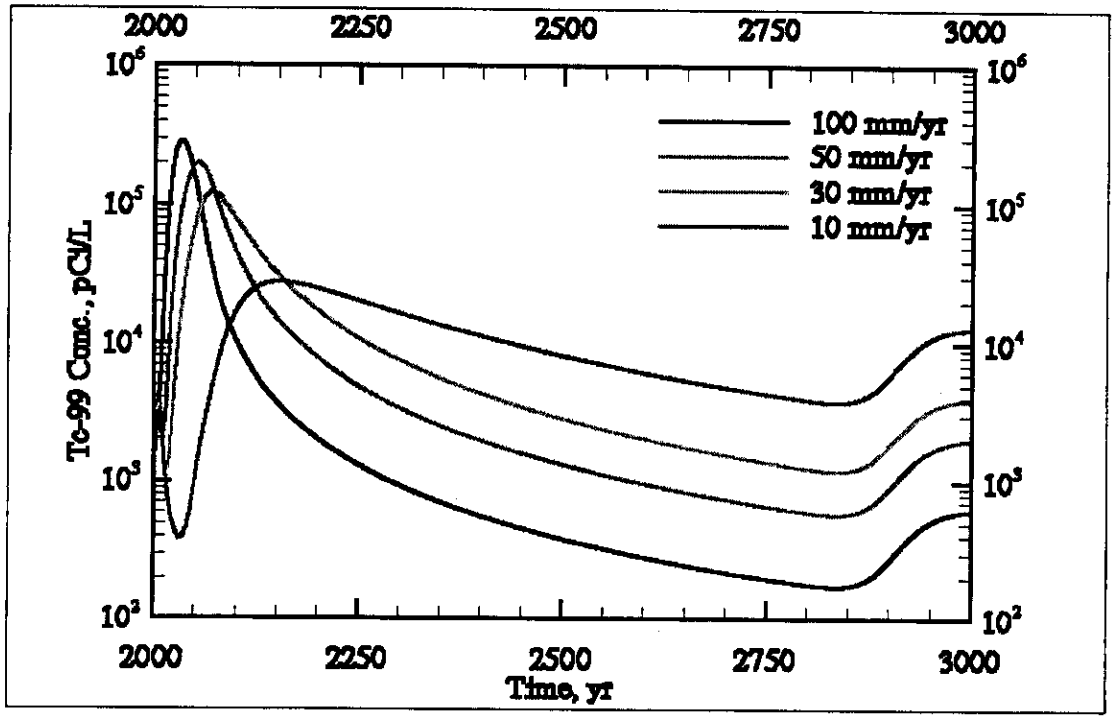

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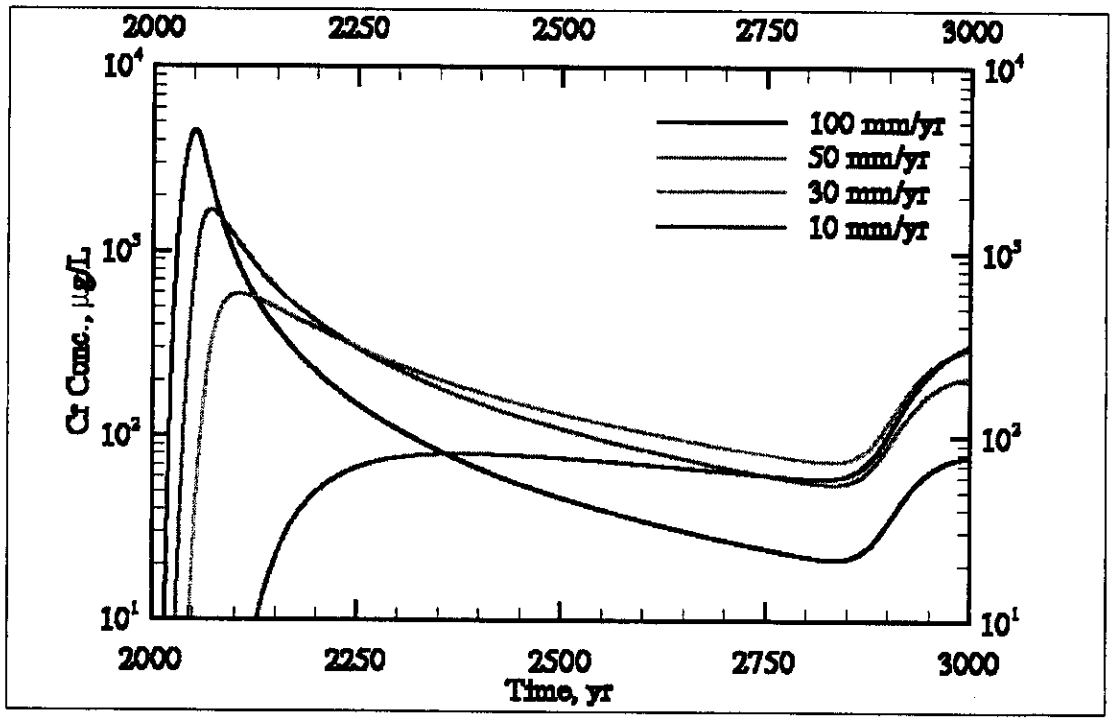

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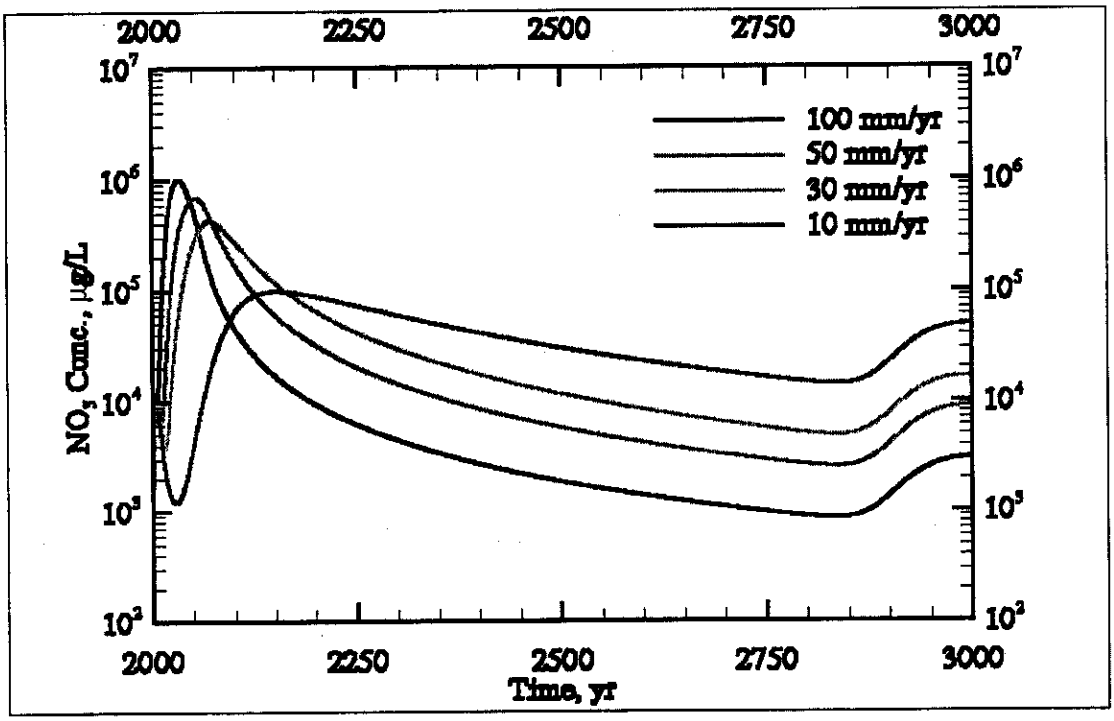

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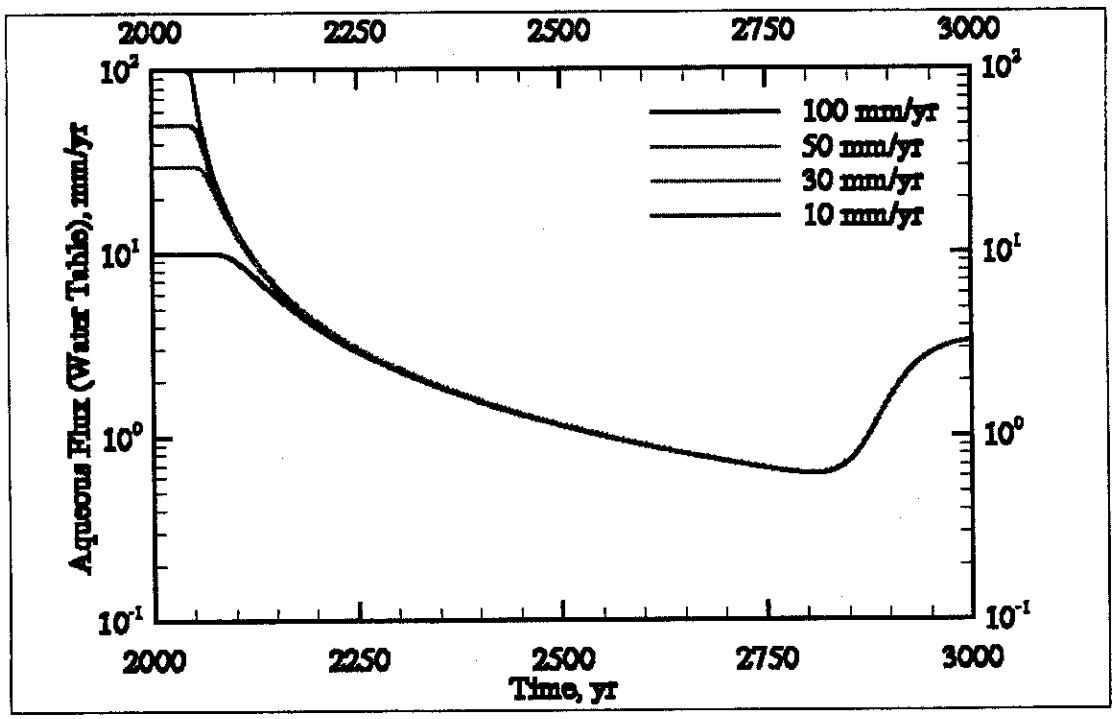

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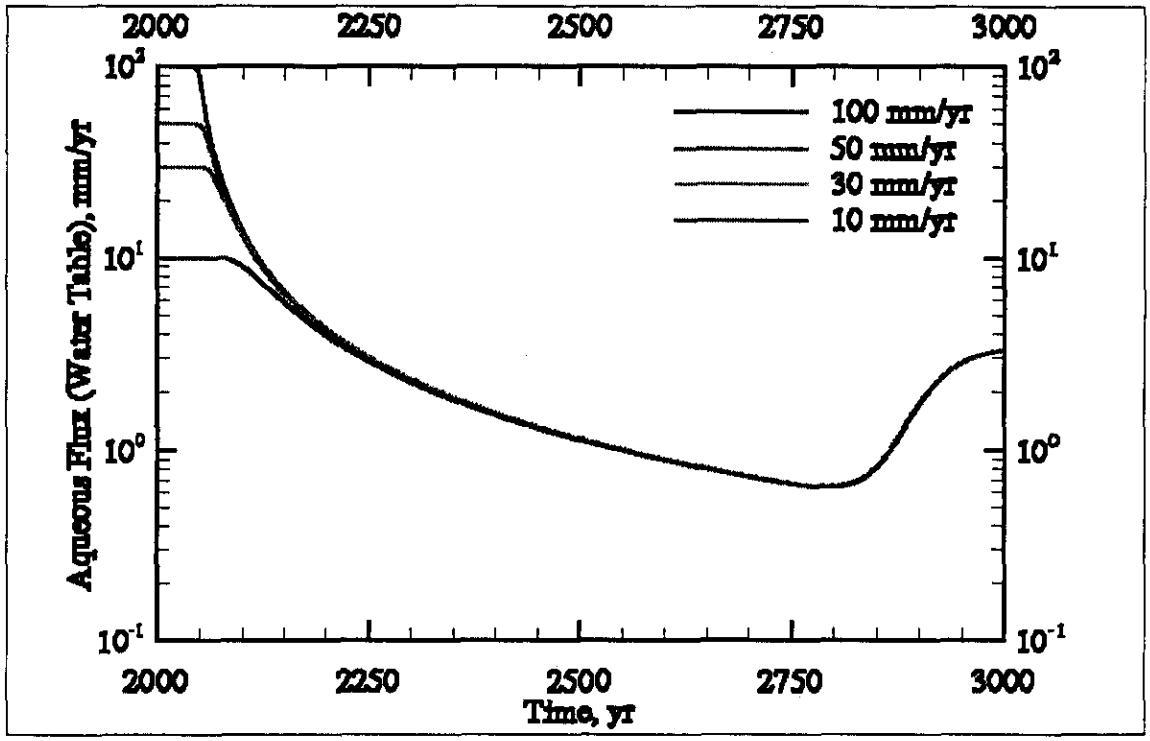

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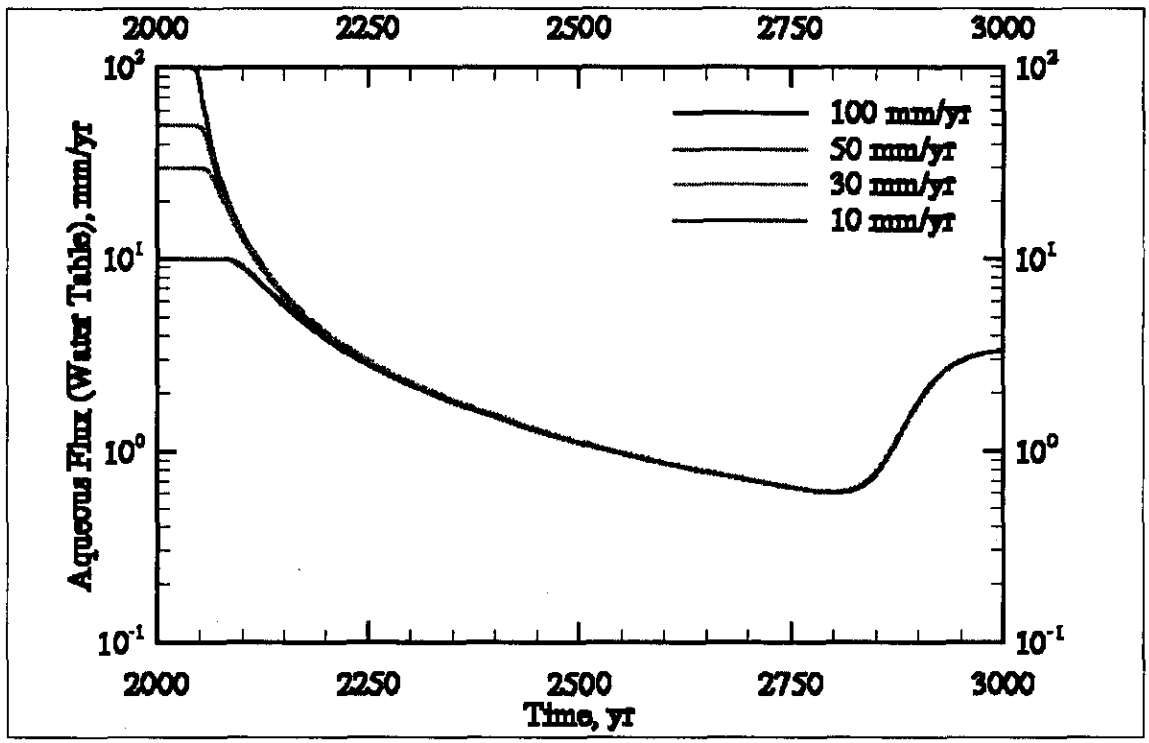

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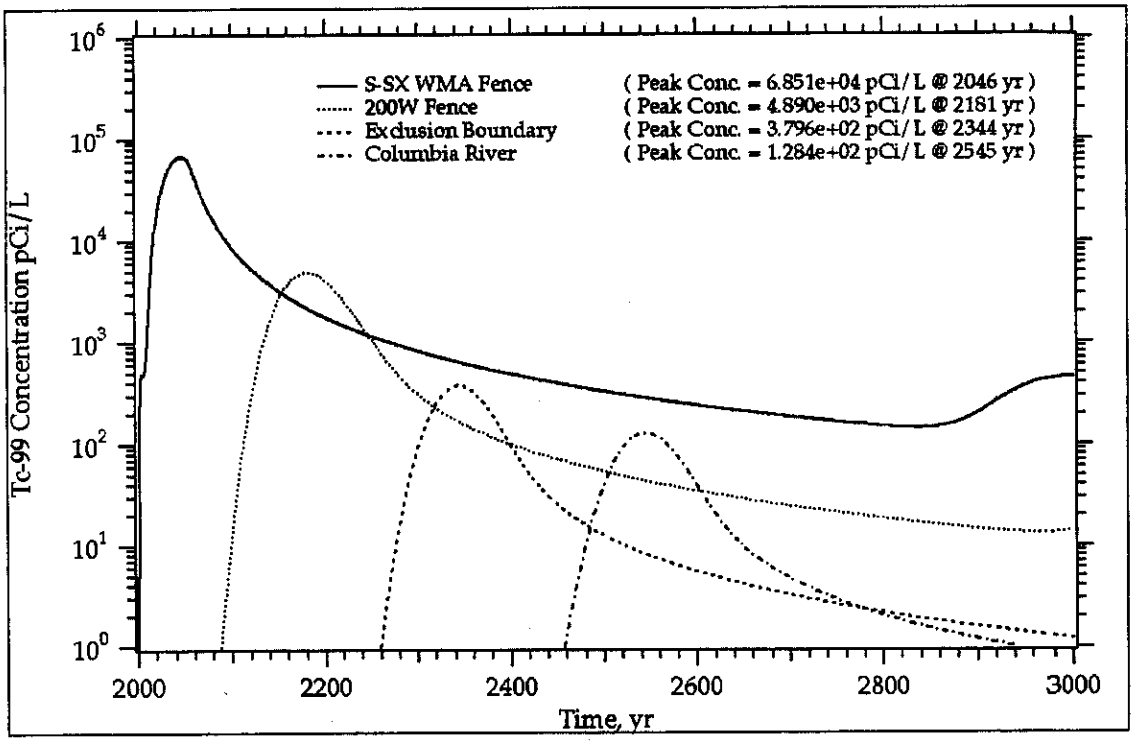

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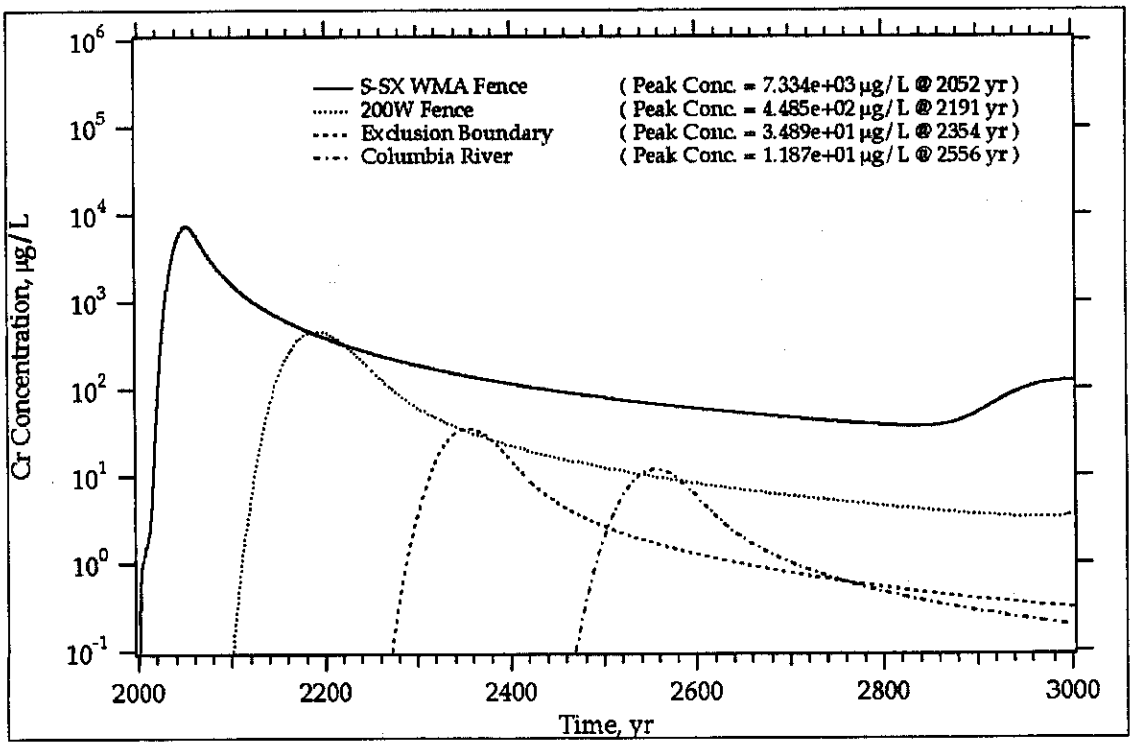

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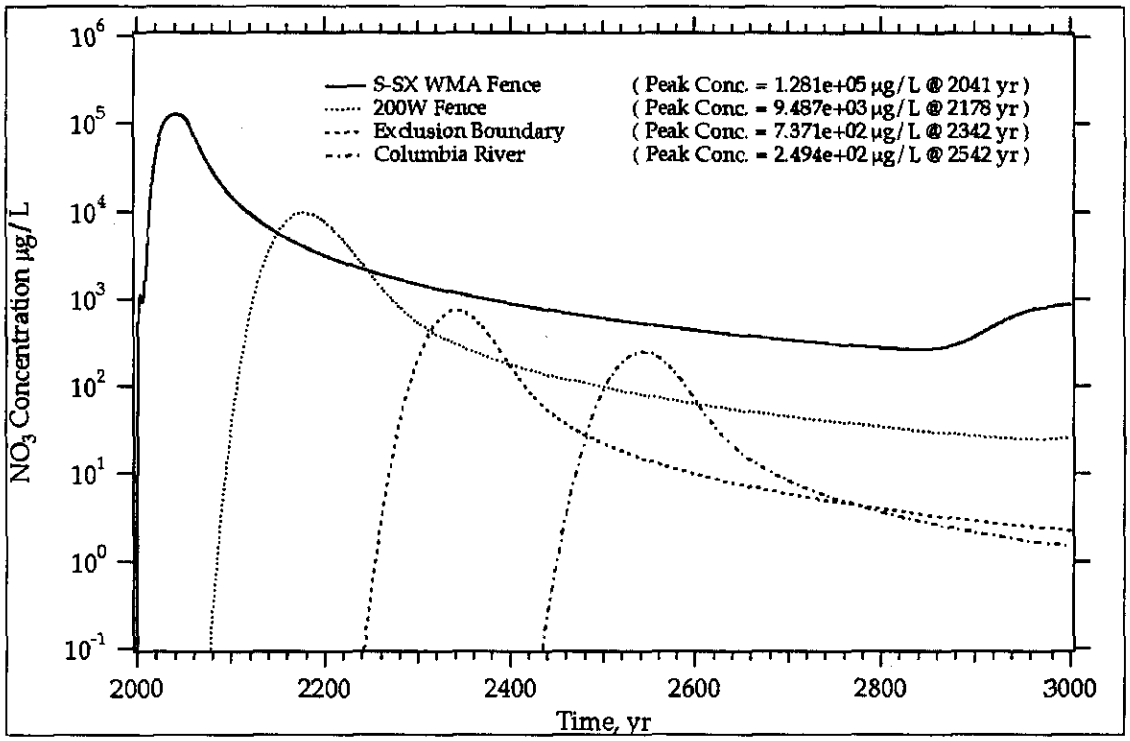

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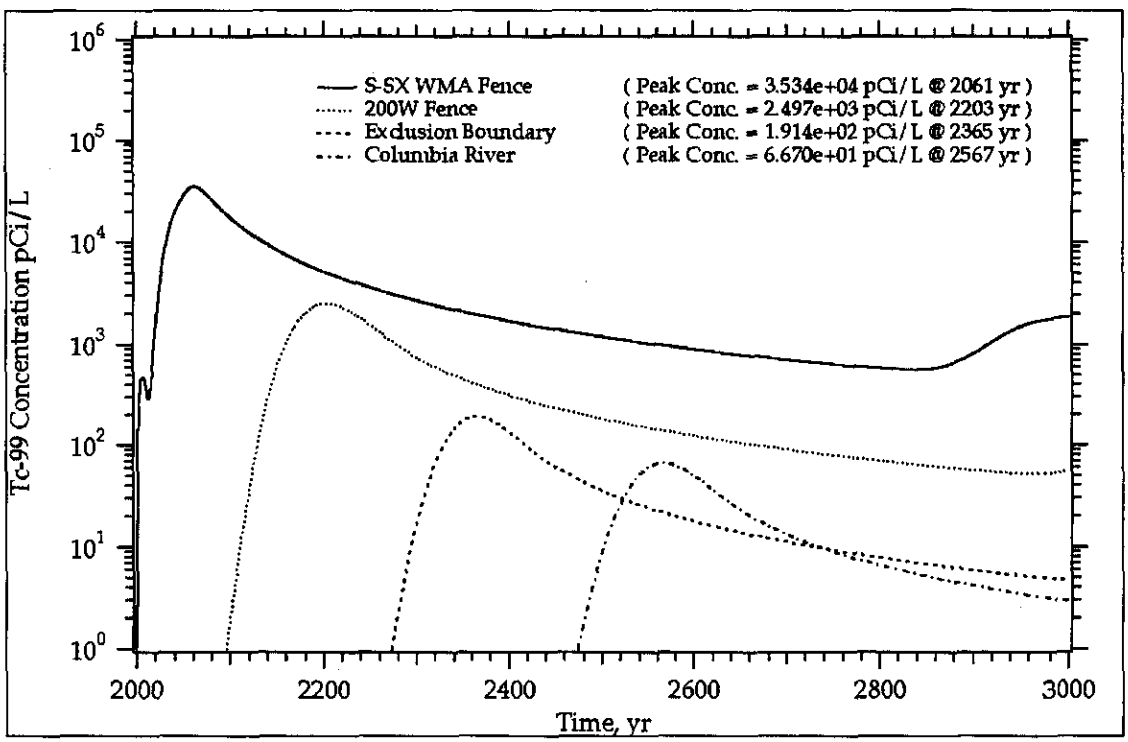

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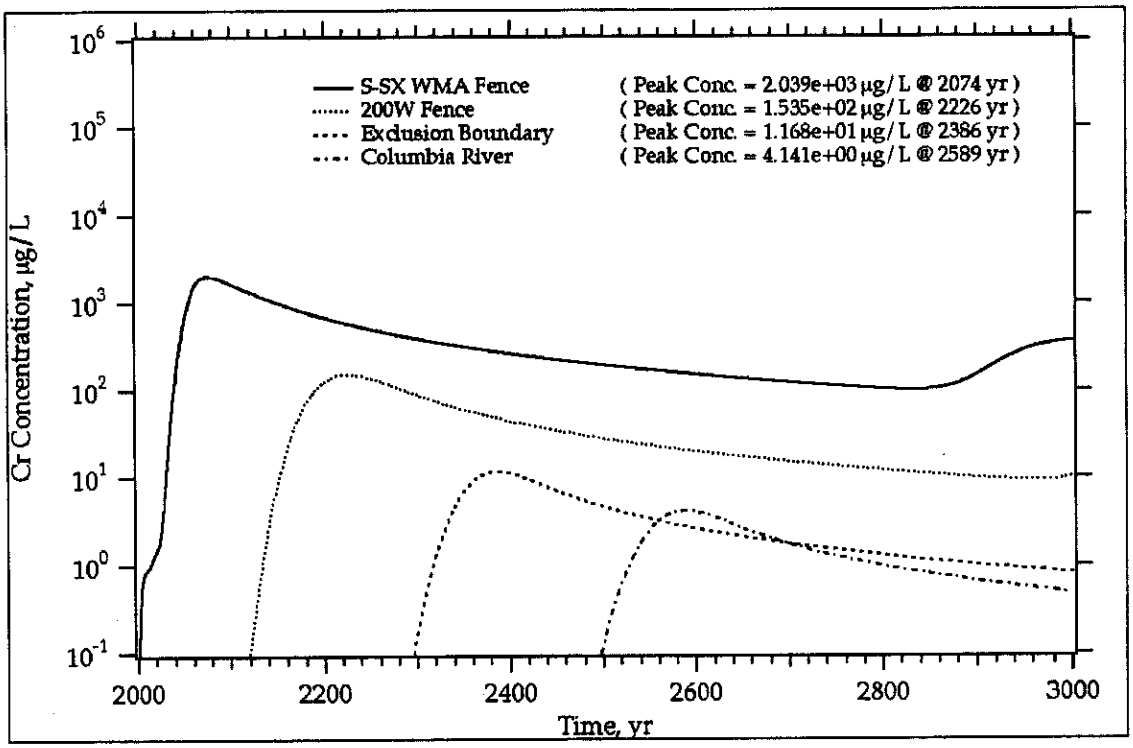

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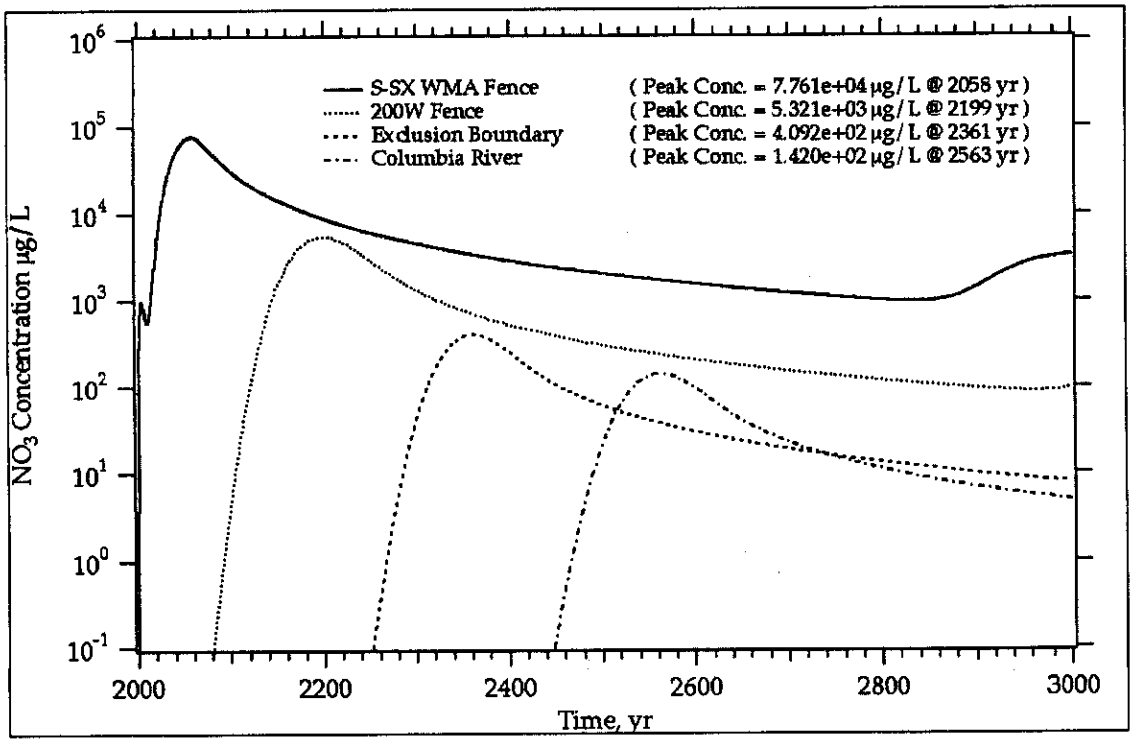

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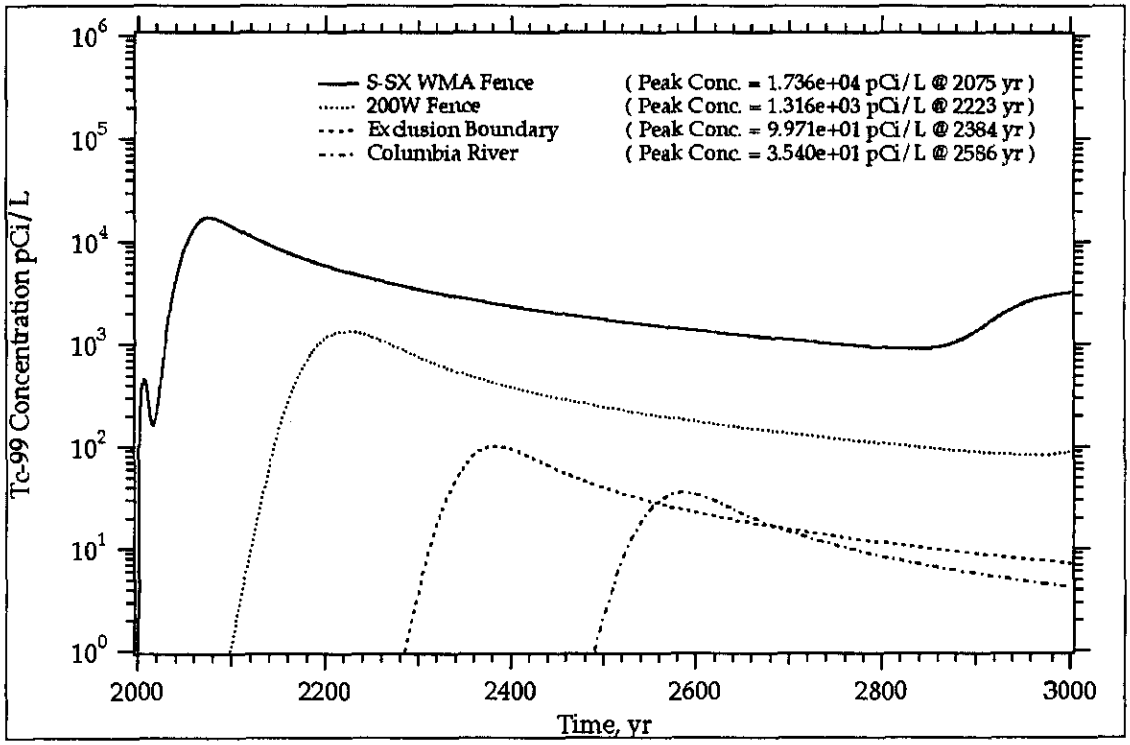

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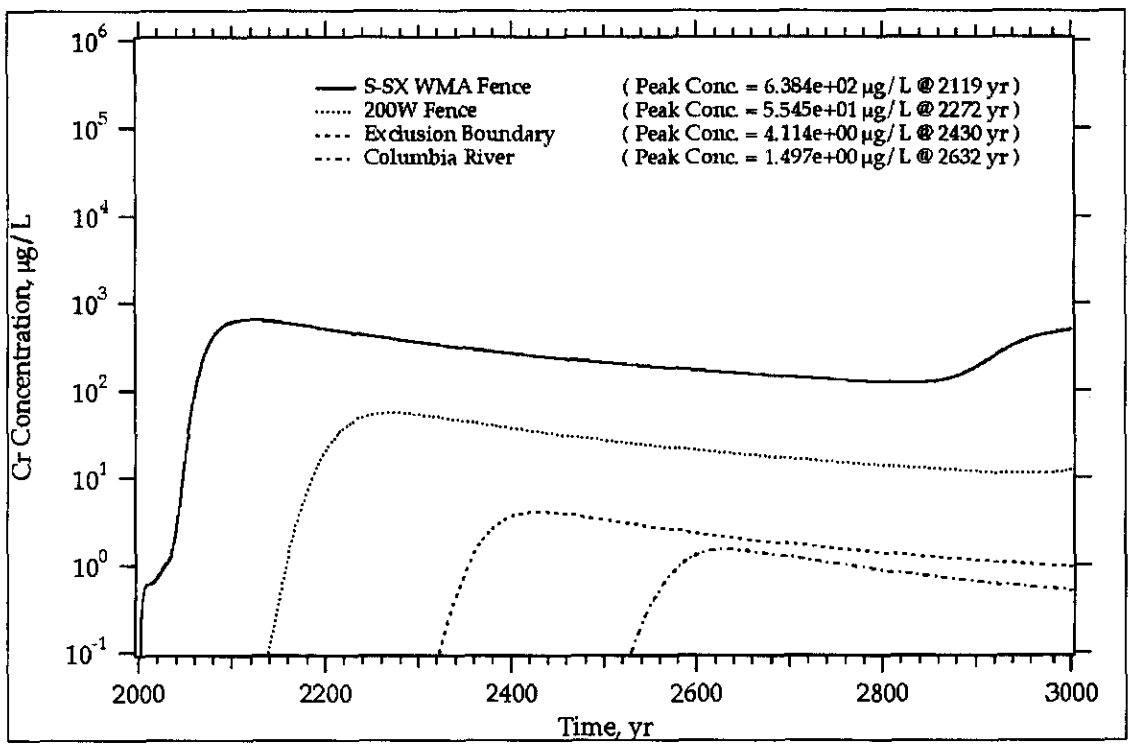

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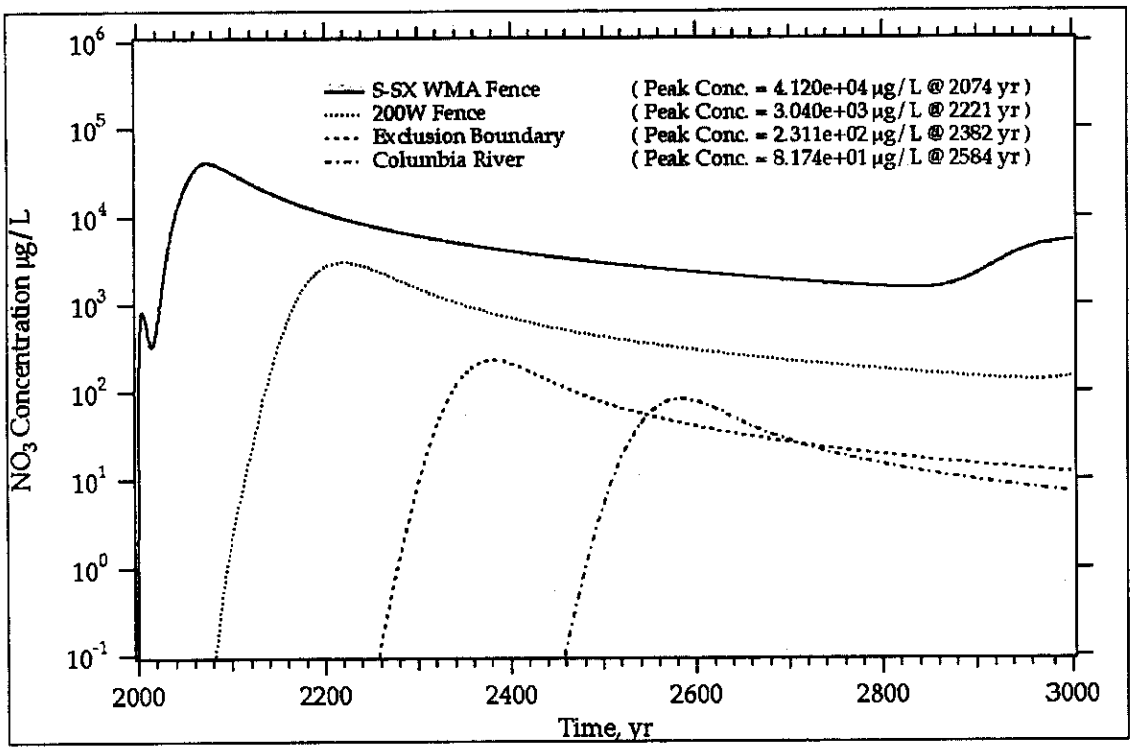

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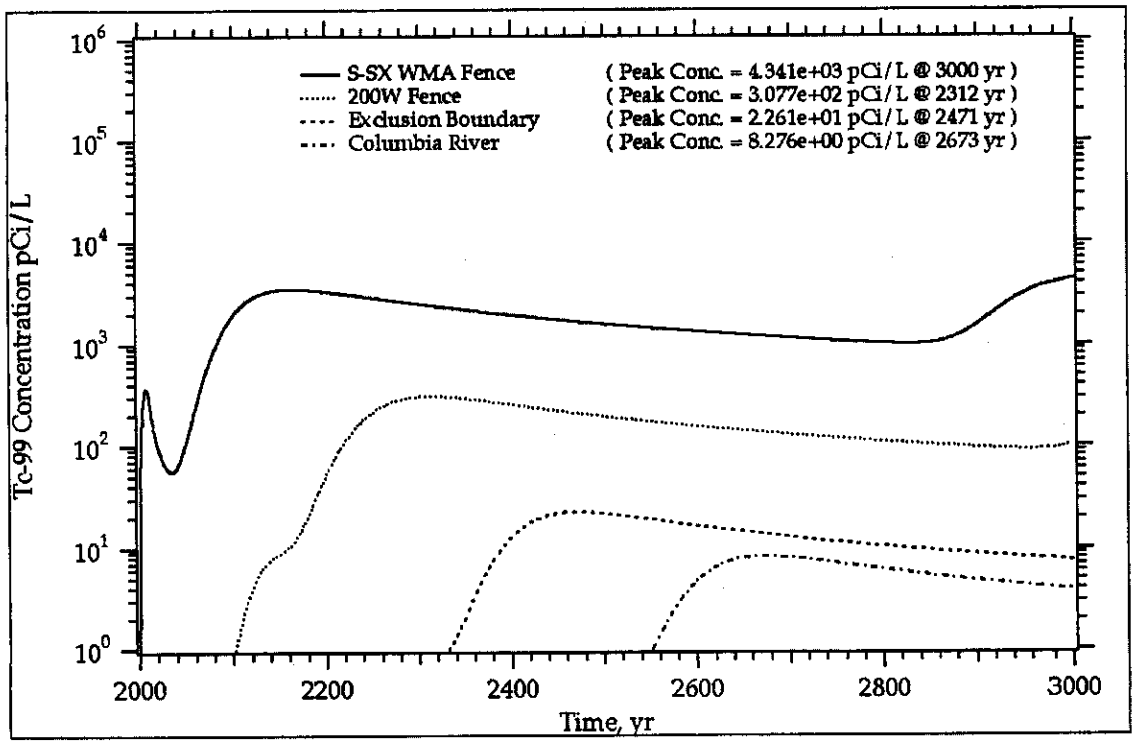

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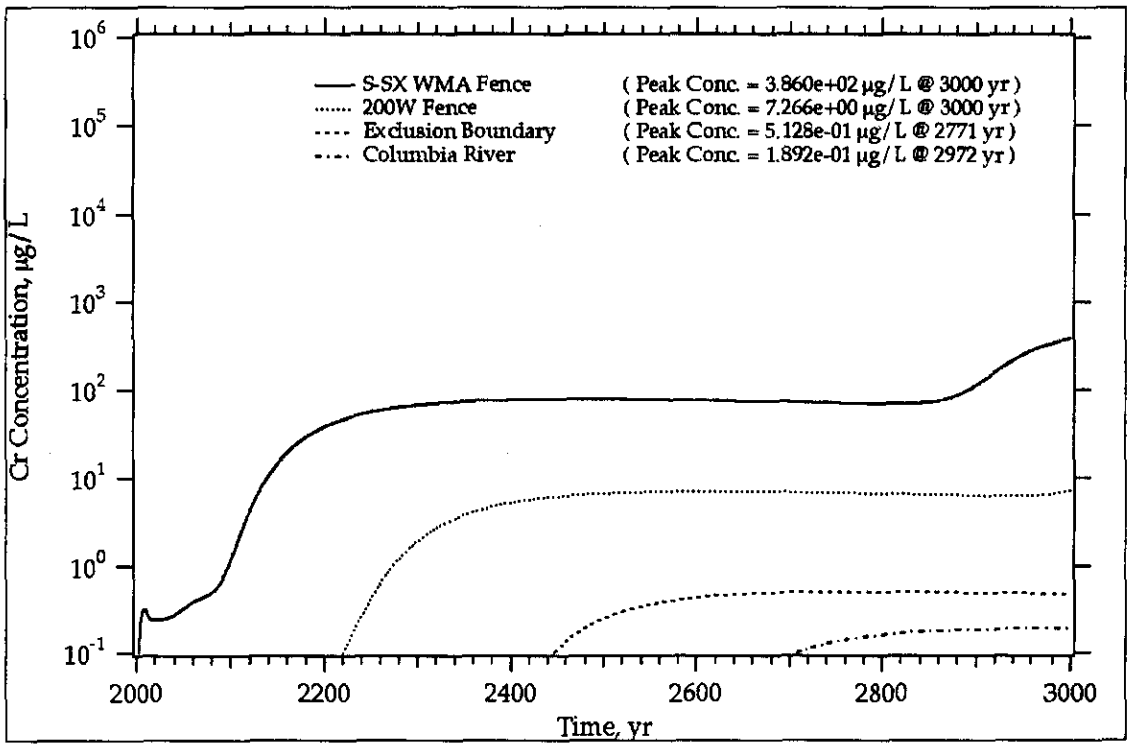

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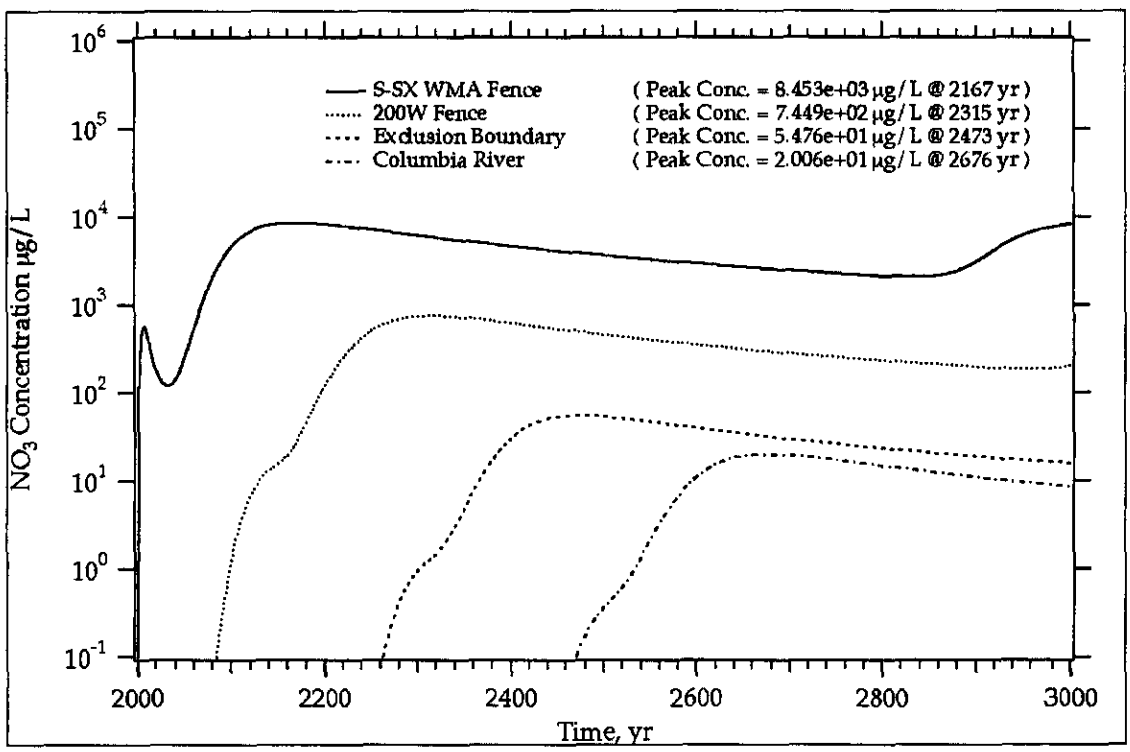

APPENDIX F

COST AND IMPLEMENTABILITY OF INTERIM MEASURES AND INTERIM CORRECTIVE MEASURES

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LIST OF TERMS

ICM	interim corrective measure
WMA	waste management area

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F.1.0 INTRODUCTION

This "Cost And Implementability of Interim Measures and Interim Corrective Measures" appendix describes the interim measures and interim corrective measures (ICMs) that have been evaluated as they relate to the waste management area (WMA) S-SX. Interim measures are initial response actions that can be taken while characterization activities are underway and long-term strategies are being developed to reduce the impacts of tank leaks on groundwater. Interim measures do not require comprehensive evaluation in a corrective measures study. ICMs are response actions having the objective of reducing contaminant migration to groundwater to acceptable regulatory levels and which require a balancing of risk, benefits, and costs.

Interim measure response actions that have been studied are discussed and how these interim measures are being implemented is addressed. Interim measures identified to date focus on actions to minimize infiltration and contaminant migration to groundwater. This appendix also provides estimated costs for implementing the interim measures at WMA S-SX as reflected in *Engineering Report, Single-Shell Tank Farms Interim Measures to Limit Infiltration Through the Vadose Zone* (Anderson 2001).

In general, ICMs involve a substantial commitment of resources, require a more thorough evaluation, and are intended to provide a more permanent solution to the long-term threats posed by a release. For those measures where engineering studies have been performed, results from those studies will be summarized. For other potential ICMs, it is premature to provide a detailed discussion of the associated cost and implementability issues. Detailed evaluation of the ICMs will be undertaken in a corrective measures study, or an accelerated corrective measures study pending results of this field investigation report.

F.2.0 INTERIM MEASURES

The engineering report (Anderson 2001) was prepared to assess potential measures to limit infiltration through the vadose zone at the single-shell tank farms. That study evaluates leaking water lines, wells within the single-shell tank farms, and surface water (both recharge and run-on). Included in this study are a number of interim measures that are 'good housekeeping' actions, which should be considered for implementation because they would reduce water infiltration at the tank farms and limit the migration of contamination through the vadose zone. The recommended interim measures include the following:

- Abandoning all active water lines within and near the tank farms
- Decommissioning unfit-for-use wells within the tank farms
- Establishing control measures to prevent water from running onto the tank farm from outside the fence.

These three measures could be implemented without a detailed technical evaluation. Summaries of the work that has been performed in these areas are provided in the following sections.

F.2.1 ABANDONING ACTIVE WATER LINES

Combined, the S and SX tank farms have approximately 1,930 m (6,300 ft) of active water lines that have been abandoned to eliminate persistent leaks and prevent future water line breaks. These lines were mainly installed during original tank farm construction and have exceeded their design life.

F.2.2 DECOMMISSIONING UNFIT-FOR-USE WELLS

Wells that are unfit for use are potential preferential pathways for contaminant migration to reach the groundwater. The engineering report (Anderson 2001) identifies a number of wells in the S and SX tank farms that should be decommissioned.

F.2.3 BERMS

Run-on control consists of berms, ditches, and asphalt curbs constructed outside the water control area to prevent surface water outside the tank farm from flowing on the tank farm areas. The engineering report (Anderson 2001) recommends that, regardless of which interim measures are selected to reduce infiltration within the WMA, run-on control be established to prevent surface water from entering the WMA from outside sources. Run-on controls have been constructed at the S, SX, T, TX, TY, and U tank farms.

F.3.0 INTERIM CORRECTIVE MEASURES

ICMs have the same overall purpose as interim measures. Because of their size, complexity, or impact to operations, a more careful study must be performed before ICMs are implemented. Many potential ICMs have been identified; however, it is recognized that some of these potential ICMs are likely to be implemented sooner than others. Thus, this section describes the two sets of ICMs separately.

F.3.1 IDENTIFICATION OF POTENTIAL NEAR-TERM INTERIM CORRECTIVE MEASURES

The activities that have been undertaken to identify potential ICMs for the WMAs are described below.

- In 1992 an engineering study that evaluated 4 approaches for reducing surface infiltration at the WMAs (Young et al. 1992) was completed. The approaches evaluated were (1) polymer-modified asphalt, (2) fine-soil cover, (3) buildings (structures), and (4) flexible membrane liners. The engineering study concluded that implementation of these approaches for all of the WMAs ranged from $40 million to $158 million. Cost and other factors were the reasons that none of the approaches were implemented.

- On May 4 through 6, 1999 an innovative treatment remediation demonstration forum was held in Richland, Washington to discuss techniques for reducing and monitoring infiltration at the single-shell tank farms. The U.S. Department of Energy, Hanford Site contractors and various vendors from throughout the United States and Canada attended. Pacific Northwest National Laboratory summarized this conference in a two-volume report, *Reducing Water Infiltration Around Hanford Tanks* (Molton 1999). Four technical sessions were conducted to discuss (1) moisture monitoring and characterization, (2) structures or buildings to cover the WMAs, (3) surface modifications or covers, and (4) near-surface modifications (barriers and permeability reduction techniques). The forum concluded that existing commercial capabilities could be employed to reduce and monitor infiltration in the WMAs, but that no one technology was appropriate for all seven WMAs. Another conclusion of the forum was that the costs shown in Young, Schroeder, and Carver (1992) were 50% to 80% higher than those reflected by the vendors attending the forum. During the course of the forum a number of U.S. Department of Energy officials and U.S. Department of Energy site subcontractors addressed site-specific constraints that the vendors may not have been taken into account before they submitted their estimated or typical-unit costs.

- In June 2000 the U.S. Department of Energy prepared *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas* (DOE-RL 2000). Section 4.2 of DOE-RL (2000) identifies a number of general response actions, technology and process options associated with each general response action, and screened each option based on effectiveness, ability to implement, worker safety and cost. While the majority of the processes discussed fell into the ICM category, surface caps, overhead structures and run-on and run-off controls, that are considered interim measures, were identified.

- In April 2001 an engineering report (Anderson 2001) was completed. In addition to evaluating water lines and wells within the WMAs, the report also evaluated surface water both from natural causes and catastrophic events. Alternatives considered in that report include (1) no action, (2) site grading, (3) geo-fabric liners, (4) asphalt concrete paving, (5) building enclosure with asphalt apron, and (6) run-on control. The report recommends that a combination of a building enclosure with asphalt apron and run-on control be implemented. While the building enclosure was not the preferred option (because of the cost) the report concluded that it provided the best operational and technical alternative.

The three potentially viable interim corrective measures selected from among those identified were (1) near-surface barriers, (2) surface barriers, and (3) overhead structures.

F.3.2 NEAR-SURFACE BARRIER

This section describes and evaluates the near-surface barrier option as a near-term ICM, its implementation at WMA S-SX, and costs.

F.3.2.1 Description

The near-surface barrier would consist of an impervious, geo-fabric (geomembrane liner or geosynthetic clay) system over the entire WMA S-SX to direct surface water to the outer boundaries of the tank farm. A run-off collection system consisting of ditches and pipes would be required to route collected surface water to existing drainage routes.

F.3.2.2 Implementation at Waste Management Area S-SX

Implementation of a near-surface barrier would be disruptive to other tank farm activities. The entire area, 18,000 m^2 (194,000 ft^2) at the S tank farm and 20,500 m^2 (220,000 ft^2) at the SX tank farm, would require hand excavation to remove 30 cm (12 in.) of existing soil and subsequent replacement of this soil as a cover over the liner to allow for traffic. The soil would have to be hand excavated because of the tank dome-loading restrictions and the many utilities within the tank farm. Some of these utilities may require support during construction or relocation to a depth below the liner. Installation of the near-surface barrier would require additional time from a typical installation because of the many obstructions protruding above the surface. During the period that the near-surface barrier is required to control surface water, repairs would be required if any tank farm activities required work below the liner.

F.3.2.3 Cost

The estimated costs cited in the engineering report (Anderson 2001) for implementation of a subsurface barrier are $7.1 million for the S tank farm and $8.1 million for the SX tank farm.

F.3.2.4 Evaluation Criteria

Tables F.1 and F.2 show decision criteria, weight factors, and score for the near-surface barrier option. For this evaluation, the weight factor was multiplied by one through five to determine the weighted score. A score of one represents little or no impact of the activity to the decision

criterion, and a score of five represents a greatly increased impact of the activity. Note that the weighted factor and decision criteria are the same for all three viable ICMs.

Table F.1. S Tank Farm Near-Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	4	20	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	2	4	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	2	8	20
Schedule	3	3	9	15
Proven technology	3	1	3	15
Maintainability	3	3	9	15
Operability	2	2	4	10
Constructability	3	4	12	15
Decontamination, decommissioning, and disposal	4	3	12	20
Total Weighted Score			**99**	**185**

Source: Anderson (2001).

Table F.2. SX Tank Farm Near-Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	4	20	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	2	4	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	2	8	20
Schedule	3	3	9	15
Proven technology	3	1	3	15
Maintainability	3	2	6	15
Operability	2	2	4	10
Constructability	3	3	9	15
Decontamination, decommissioning, and disposal	4	3	12	20
Total Weighted Score			**93**	**185**

Source: Anderson (2001).

F.3.3 INTERIM SURFACE BARRIER

This section describes and evaluates the interim surface barrier option as a near-term ICM, its implementation at WMA S-SX, and cost.

F.3.3.1 Description

The only surface barrier evaluated is a 6 cm (2.5 in.) layer of asphalt cement pavement. Surface barriers that were not evaluated, but have been used successfully on other projects include various liquid and solid reagents that are applied and allowed to penetrate the surface materials or are mixed with the surface materials to form a crust. A run-off collection system consisting of ditches and pipes would be required to route collected surface water to existing drainage routes.

F.3.3.2 Implementation at Waste Management Area S-SX

Implementation of a surface barrier would be disruptive to other tank farm activities. The entire area, 18,000 m^2 (194,000 ft^2) at the S tank farm and 20,500 m^2 (220,000 ft^2) at the SX tank farm, would require hand excavation to remove 10 cm (4 in.) of existing gravel cover, which would be taken from the site and disposed of if contaminated or used in the production of the asphalt. The material would have to be hand excavated because of the tank dome-loading restrictions and the many utilities within the tank farm. Some of these utilities may require relocation if they are near the surface following removal of the 10 cm (4 in.) of existing materials. Installation of the surface barrier would also take additional time from typical installations to seal the numerous obstructions protruding above the surface.

Adequate compaction of both the subgrade and the asphalt will not be obtained because of the obstructions within the tank farm and the tank dome-loading restrictions. During the period that the surface barrier is required to control surface water, traffic loading may do substantial damage to the surface barrier. The cost to repair the asphalt barrier using the special fine mix could be excessive.

F.3.3.3 Cost

The estimated costs cited in the engineering report (Anderson 2001) for implementation of a surface barrier are $3.4 million for the S tank farm and $3.9 million for the SX tank farm.

F.3.3.4 Evaluation Criteria

Tables F.3 and F.4 show decision criteria, weight factors, and score for the interim surface barrier option. For this evaluation, the weight factor was multiplied by one through five to determine the weighted score. A score of one represents little or no impact of the activity to the decision criterion, while a score of five represents a greatly increased impact of the activity. Note that the weighted factor and decision criteria are the same for all three viable ICMs.

Table F.3. S Tank Farm Interim Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	3	15	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	3	6	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	3	12	20
Schedule	3	3	9	15
Proven technology	3	2	6	15
Maintainability	3	4	12	15
Operability	2	2	4	10
Constructability	3	4	12	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			**110**	**185**

Source: Anderson (2001).

Table F.4. SX Tank Farm Interim Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	3	15	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	3	6	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	3	12	20
Schedule	3	3	9	15
Proven technology	3	2	6	15
Maintainability	3	2	6	15
Operability	2	2	4	10
Constructability	3	3	9	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			**101**	**185**

Source: Anderson (2001).

F.3.4 OVERHEAD STRUCTURE

This section describes and evaluates the overhead structure option as a near-term ICM, its implementation at WMA S-SX, and cost.

F.3.4.1 Description

The overhead structure would consist of an enclosed shelter covering the majority of the surface water control area of the WMA. An asphalt apron would be constructed around the perimeter of the structure to capture surface water and route that water to a run-off collection system.

F.3.4.2 Implementation at Waste Management Area S-SX

Erection of the overhead structure would be more complicated than typical erections because of tank dome-loading limitations. This option may require larger-than-normal cranes for erection of the structure and coverings. To span the entire width of the S or SX tank farm (104 m [340 ft] and 107 m [350 ft], respectively) would limit the weight of equipment that could be attached to the structure (e.g., monorails; lighting; heating, ventilation, and air conditioning). Engineers would have to determine if foundations could be constructed in between the tanks at the S and SX farms to decrease the free span distance and to allow greater auxiliary loading of the structures' supports.

The evaluation of which overhead structure to construct must take into account the free span distances of 104 m (340 ft) and 107 m (350 ft). To provide a structure with this free span, a rigid-framed structure may be required. An evaluation should be made of intermediate supports to be located between the tanks. This would allow the structure to be equipped with accessories that may increase productivity of future tank farm operations (e.g., monorail; lighting; and heating, ventilation, and air conditioning). The use of intermediate supports would also allow the use of enclosure systems other than a rigid-framed structure.

The evaluation of overhead structures should also include recently emerging or advanced technologies, (e.g., a domed structure). This technology is purported to provide greater strengths at less cost than conventional structures.

F.3.4.3 Cost

The estimated costs presented in the engineering report (Anderson 2001) for implementation of a building enclosure with an asphalt apron are $18.3 million for the S tank farm and $20.8 million for the SX tank farm. Depending on the closure technology used at WMA S-SX, a confinement facility would be required (DOE-RL 2000). If a confinement facility is not required, production would be increased 30% by working within an enclosure (Anderson 2001). Credit was not given to these items in determination of the costs.

F.3.4.4 Evaluation Criteria

Tables F.5 and F.6 show decision criteria, weight factors, and score for the overhead structure option. For this evaluation the weight factor was multiplied by one through five to determine the weighted score. A score of one represents little or no impact of the activity to the decision

criterion, while a score of five represents a greatly increased impact of the activity. Note that the weighted factor and decision criteria are the same for all three viable ICMs.

Table F.5. S Tank Farm Overhead Structure Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	2	10	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	5	10	10
Tank integrity	5	2	10	25
Future retrieval and processing	4	1	4	20
Schedule	3	2	6	15
Proven technology	3	1	3	15
Maintainability	3	2	6	15
Operability	2	1	2	10
Constructability	3	2	6	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			**76**	**185**

Source: Anderson (2001).

Table F.6. SX Tank Farm Overhead Structure Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	2	10	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	5	10	10
Tank integrity	5	2	10	25
Future retrieval and processing	4	1	4	20
Schedule	3	2	6	15
Proven technology	3	1	3	15
Maintainability	3	2	6	15
Operability	2	1	2	10
Constructability	3	2	6	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			**76**	**185**

Note: No credit was given for an estimated 30% productivity improvement for tank farm activities following structure construction or that closure activities may require an enclosure.

Source: Anderson (2001).

F.3.5 NEAR-TERM INTERIM CORRECTIVE MEASURES SUMMARY

This section summarizes the evaluation of the three potential near-term ICMs (near-surface barriers, surface barriers, overhead structures) and provides a comparison of the evaluation criteria and conclusions based on the evaluation. The near-surface barrier, surface barrier, and overhead structures options evaluated presented problems for implementation. Implementation of the near-surface and surface barriers would require extensive hand labor because of tank dome-loading restrictions and numerous obstructions protruding to the surface. Implementation of the overhead structures would require free span distances that may stretch the limits of current technologies involved in construction or would require foundations to be constructed in the area between tanks.

Table F.7 summarizes the estimated costs for each option by tank farm.

Table F.7. Interim Corrective Measures Cost Summary

Option	S Tank Farm Estimated Costs	SX Tank Farm Estimated Costs
Near-surface barriers	$7,058,000	$8,123,000
Surface barriers	$3,373,000	$3,892,000
Overhead structures	$18,245,000	$20,831,000

Table F.8 summarizes the evaluation criteria and weighted scores for the options evaluated for minimizing infiltration at the S and SX tank farms.

Table F.8. Interim Corrective Measures Evaluation Summary

Decision Criteria	Weighted Score S Tank Farm			Weighted Score SX Tank Farm		
	Subsurface Barrier	Surface Barrier	Overhead Structure	Subsurface Barrier	Surface Barrier	Overhead Structure
Safety	20	15	10	20	15	10
Regulatory compliance	3	3	3	3	3	3
Life cycle cost analysis	4	6	10	4	6	10
Tank integrity	15	15	10	15	15	10
Future retrieval and processing	8	12	4	8	12	4
Schedule	9	9	6	9	9	6
Proven technology	3	6	3	3	6	3
Maintainability	9	12	6	6	6	6
Operability	4	4	2	4	4	2
Constructability	12	12	6	9	9	6
Decontamination, decommissioning, and disposal	12	16	16	12	16	16
Total Weighted Score	**99**	**110**	**76**	**93**	**101**	**76**

Source: Anderson (2001).

WMA = waste management area.

Any of the three potential near-term ICMs could be implemented to reduce infiltration at WMA S-SX. The cost versus benefits (i.e., reduction in contaminant concentrations in the groundwater) of implementing any of the interim measures should be considered because sufficient time may have elapsed between when the leaks occurred and the present to effectively reduce the contaminant concentrations in the groundwater. Additionally implementing ICMs may divert funding from other tank waste remediation activities such as waste retrieval.

The evaluation of options in Anderson (2001) resulted in a recommendation to implement the overhead structure. This recommendation is based on the summary of the evaluation criteria that ranked the overhead structure lowest for both S and SX tank farms. The weighted scores presented are subjective and represent a best-estimate effort to account for the relative importance of the different evaluation criteria presented. The estimated cost for the overhead structure is considerably higher than the other options evaluated and this variation is not well captured in the weighted ranking. Anderson (2001) did not provide credit for an estimated 30% productivity gain for tank farm operations within the enclosure or that enclosure would be required for certain tank farm closure alternatives.

F.3.6 ADDITIONAL POTENTIAL INTERIM CORRECTIVE MEASURES

This section identifies additional potential ICMs for consideration at WMA S-SX. These ICMs generally involve a greater commitment of resources than the ICMs discussed in Section F.3.5 and require a more thorough site-specific evaluation prior to selecting an ICM for implementation at WMA S-SX. Any evaluation of ICMs must include consideration of continued storage of waste in the tanks and future plans to retrieve waste from the tanks as well as cost versus benefits of the technologies in terms of reducing groundwater impacts. If warranted, detailed evaluation of ICMs for WMA S-SX would be conducted in a corrective measures study.

F.3.6.1 Interim Corrective Measure Technologies for Soil Contamination

This section describes the ICM technologies for soil contamination that are described in the Phase 1 RFI/CMS work plan (DOE-RL 2000) and in *Feasibility Study of Tank Leakage Mitigation Using Subsurface Barriers* (Treat et al. 1995).

F.3.6.1.1 Containment Technologies. Containment technologies use physical measures to isolate and reduce the horizontal and vertical movement of contaminants.

Grout Walls. Grout walls are formed by either injecting grout under pressure directly into the soil matrix (permeation grouting) or in conjunction with drilling (jet grouting) at regularly spaced intervals to form a continuous low-permeability barrier. Grout walls could be installed either vertically or directionally in an effort to create a barrier underneath the contaminant plume in the soil (DOE-RL 2000). A large number of boreholes would be required to construct a barrier. A grout containment barrier was previously evaluated for the AX tank farm as a means to contain potential retrieval leakage (Norman 1999). In the AX tank farm study, grout injection borings were directionally drilled beneath the tanks on approximately 1.5 m (5 ft) centers. Installation of a horizontal grout blanket beneath the four tanks in the AX tank farm was estimated to cost approximately $200 million. One of the issues identified with this technology

was the difficulty in verifying the integrity of the grout barrier. Grout walls are potentially applicable at WMA S-SX; however, the contamination has reached the groundwater and the ability to implement this technology and determine its effectiveness are of concern and would require further evaluation.

Cryogenic Barrier. Cryogenic (or freeze-wall) barriers are formed by recirculating chilled brine or other refrigerants through an array of closely spaced wells or freeze pipes. As the soil surrounding and between these wells or freeze pipes cools and freezes, the water in the voids freezes and expands. The freezing and expanding water effectively creates an impermeable barrier. Cryogenic barriers may be applicable at WMA S-SX although it is unclear if the technology would perform as planned if it were necessary to inject supplemental water into the highly transmissive soils of the Hanford Site. In addition, maintenance of a cryogenic barrier requires a long-term commitment of resources. Contamination has reached the groundwater, and the ability to implement this technology and determine its effectiveness is of concern and would require further evaluation.

Dynamic Compaction. Dynamic compaction is used to densify the soil; compact buried solid waste; and reduce the void spaces in the soil, which can reduce the hydraulic conductivity of the soil and the mobility of contaminants. This process is accomplished by dropping a heavy weight onto the ground surface. This technology is commonly used in coordination with caps; it would have limited application in the tank farm area because of the graveled surface and the potential tank dome-loading during the compaction process.

Circulating Air Barriers. The circulating air barrier technology would create a dry zone under the area of confinement through which no liquids could penetrate until a critical liquid saturation was exceeded. For most sediments at the Hanford Site, critical saturation is on the order of 5% to 25%. The water under the tanks is essentially immobile and, if kept at or below the critical saturation value, would remain immobile. Circulating air barrier technology injects dry air from an array of either vertical or horizontal wells. The air is forced through porous soils to extraction wells, vaporizing water in the process. Circulating air barrier technology is applicable at WMA S-SX although no large-scale field tests have been performed.

Radio Frequency Desiccating Subsurface Barriers. A radio frequency heating process can be used for the formation of an active desiccating barrier underneath underground storage tanks. Electrodes are installed in the soil between the source of the contamination and groundwater using horizontal drilling techniques. The radio frequency energy applied to the electrodes heats a 2 to 3 m (6 to 10 ft) thick layer of soil to temperatures above 100 °C (212 °F) to evaporate the moisture. Electrodes are perforated and maintained under vacuum to remove the steam and volatile organics for aboveground treatment and disposal. Radio frequency desiccating subsurface barriers may applicable at WMA S-SX although the concept has not been tested at the Hanford Site.

Close-Coupled Injected Chemical Barriers. Unlike the concept of subsurface barriers installed at some depth below the tanks or below a containment plume as discussed previously for grout walls and cryogenic barriers, close-coupled injected chemical barriers are formed against the sides and bottom of an individual underground storage tank. It is unlikely that the close-coupled chemical barrier concept would be applicable at WMA S-SX because of the

problems of induced stresses on the tanks and the inability of installing a conical jet grout shell given the confining limitations among the Hanford Site underground storage tanks. In addition, the concept has not been tested outside of the laboratory.

Induced Liquefaction Barriers. Induced liquefaction is a close-coupled subsurface barrier option that combines the concepts of sheet metal piling to create a vertical barrier with caisson-drilled horizontal jet grouting. Although this technology may be applicable at WMA S-SX, no full-scale application of this technology for waste management or environmental restoration purposes is known.

F.3.6.1.2 Removal Technologies. Removal technologies include the excavation of contaminated soils or buried solid waste. After removal, the soil and debris may require ex situ treatment to meet disposal requirements or to reduce waste volume. Removal technologies could be considered for localized areas in the tank farms where leaks occurred from piping or diversion boxes at near-surface to mid-depth. Removal would not likely be effective for capturing the mobile contaminants because of the relatively high recharge rate in the tank farms and the elapsed time since the leaks occurred.

F.3.6.1.3 In Situ Treatment Technologies. In situ treatment technologies are oriented at treating the contamination in place to either extract the contaminants of concern or to stabilize and isolate contaminated soil to prevent migration to the groundwater.

Electrokinetic Separation. Electrokinetic separation can be used for organics, inorganics, and radioactive contaminants. This technology involves applying an electrical potential across the contaminated zone by using electrodes placed in the ground. Remediation by electrokinetics is based on the migration of water and ions in an electrical field. The application of electrokinetic separation at the tank farms may be limited since water is required to move ions between electrodes. Application in unsaturated soils may require water addition that could cause unwanted migration of contaminants.

In Situ Biodegradation. In situ biodegradation relies on microbial transformation of organic contaminants. Biodegradation is effective on organic contaminants but is not effective on radionuclides or inorganics. Therefore, this technology would have limited application in the tank farm area.

Solidification. Solidification can be used for organics, inorganics, and radiological contaminants. This process involves drilling holes to the desired depth, then injecting the solidification and stabilization agents into the soil with high-pressure pumps. Variations of solidification include jet injection and shallow-soil mixing. Jet injection involves drilling a small-diameter hole using a downward jet of air or water then pumping the solidification agent out laterally through jets located near the bottom of the drill pipe. Shallow-soil mixing is performed using a crane-mounted auger head to mix the soil and solidification agent. Solidification methods are potentially applicable at WMA S-SX. Access to contaminants beneath the tanks would be difficult and would require directional drilling or angle drilling. Solidification requires an understanding of the location and distribution of contaminants. Stabilization of large plumes extending from the base of the tank to the groundwater would

require a substantial commitment of time and resources. Solidification technologies would serve to delay the migration of contaminants to the groundwater.

Grout Injection. Grout is injected into the soil matrix, encapsulating the contaminants. The injection process produces a monolithic block that can be left in place or excavated for disposal elsewhere. Although grout injection is applicable at WMA S-SX, if the encapsulated contaminants are left in place future use of the site may be limited. Grouting contaminated soils deep in the vadose zone beneath the tanks would be an issue.

Deep Soil Mixing. Deep soil mixing is performed using large augers and injector-head systems to inject and mix solidifying agents into contaminated soil. Although deep soil mixing is applicable at WMA S-SX, if the encapsulated contaminants are left in place future use of the site may be limited. Using this technology to mix contaminated soil deep in the vadose zone directly beneath or adjacent to the tanks would be problematic.

Vitrification. Vitrification can be used for organics, heavy metals, and radionuclides. In situ vitrification involves the application of an electrical current to the soil to bring it to a temperature sufficient to melt the soil (1400 to 2000 °C [2552 to 3632 °F]). The process forms a stable, vitrified mass when cooled, chemically incorporates most inorganics including heavy metals and radionuclides, and destroys or removes all organic contaminants. In situ vitrification is probably not applicable at WMA S-SX because process depths are limited and the technology has very limited (extremely unlikely) potential for use in tank farms or near tanks that are storing waste.

Soil Flushing. Soil flushing can be used for organics, inorganics, and radioactive contaminants. In situ soil flushing involves the extraction of contaminants from the soil by injecting an extractant or elute (e.g., water or some other suitable solvent) through the contaminated soils. The extraction fluids solubilize or elute the contaminant from the soil. The resultant solution must be recovered through extraction wells and treated at the surface by a treatment system (e.g., ion-exchange system). Soil flushing is potentially applicable at WMA S-SX.

Soil Vapor Extraction. The soil vapor extraction process induces airflow through the soil matrix with an applied vacuum that facilitates the mass transfer of adsorbed, dissolved, or free phases of the contaminant to the vapor phase. Because soil vapor extraction is best used for volatile organic compounds and fuels, it would have limited application in the tank farm area.

Monitored Natural Attenuation. Monitored natural attenuation relies on natural processes to lower contaminant concentrations through physical, chemical, or other biological processes that, "under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants" (EPA 1999) until cleanup levels are met. Although natural attenuation methods may be readily implemented, significant action or commitment of resources (e.g., personnel to conduct sampling and perform analytical work, construction activity, and loss of land use) may be required.

F.3.6.1.4 Ex Situ Treatment Technologies. Ex situ technologies would be used in conjunction with removal technologies as discussed in Section F.3.6.1.2. Ex situ treatment technologies would have potential application for near-surface spills and leaks but would not have application for tank leaks near tanks used for storage of high-level waste. Ex situ treatment of contaminated

soils would likely require excavation by hand to remove contaminated soils within the tank farms. Worker exposures associated with hand excavation of soils contaminated from concentrated tank or transfer line leakage would be prohibitive. Additionally, an enclosure structure would also likely be required to reduce the potential for airborne contamination during excavation. Remote removal techniques are possible but would require research and development prior to being considered for deployment in the tank farms.

Biodegradation. Ex situ biodegradation is essentially the same as in situ biodegradation, except that the soil is excavated and placed in a system or pile where treatment is applied (DOE-RL 2000). Biodegradation is effective on organic contaminants, but is not effective on radionuclides or inorganics. Therefore, this technology would have limited application in the tank farm area.

Soil Washing. Soil washing is a process that applies to coarse-grained soils contaminated with a wide variety of metal, radionuclide, and organic contaminants. This process uses a wash solution (e.g., water) to remove soil contaminants by dissolving or suspending the contaminants in solution or concentrating them through particle size separation, gravity separation, and attrition scrubbing. The wash solution requires treatment to remove the contaminants that have been washed and desorbed from the soil. Although soil washing could be applicable at WMA S-SX, there are significant safety and contamination control issues associated with excavation of the more contaminated soils beneath the tanks, particularly while the tanks are still storing waste.

Solidification and Stabilization. Solidification and stabilization uses admixtures to encapsulate excavated soil and render inert various hazardous substances. This process is targeted at metals, radionuclides, and other organics. Stabilizing agents include cement, asphalt, and polymeric materials. Solidification and stabilization is applicable at WMA S-SX.

Thermal Desorption. Thermal desorption uses relatively low-temperature heat (150 to 425 °C [302 to 842 °F]) to volatilize organic contaminants from soil. A carrier gas or vacuum is used to collect and transport the volatilized organics to a gas-treatment system. Thermal desorption is only effective on organics, and it would have limited applicability at WMA S-SX.

Encapsulation. Encapsulation is accomplished by fixing individual particles in a solid matrix as discussed in "Solidification and Stabilization" or by enclosing a quantity of waste in an inert jacket or container. Encapsulation of contaminated soils is potentially applicable at WMA S-SX excluding the issues associated with excavation of the contaminated soils.

F.3.6.2 Interim Corrective Measure Technologies for Groundwater Contamination

This section describes the ICMs for groundwater contamination that are defined in the Phase 1 RFI/CMS work plan (DOE-RL 2000) and in *Feasibility Study of Tank Leakage Mitigation Using Subsurface Barriers* (Treat et al. 1995).

F.3.6.2.1 Hydraulic Containment: Extraction Wells. Hydraulic containment involves placement of extraction wells close along a line or surrounding an area, and pumping the groundwater to form depression zones, thereby creating a barrier to the passage of groundwater

and contaminants contained in the groundwater. The extracted groundwater may require treatment to remove the contaminants.

Hydraulic containment using extraction wells is applicable at WMA S-SX. However, this may not make sense within the context of other waste sites in the 200 Areas, and the potential exists for extracting contamination from nearby cribs and environmental restoration disposal sites.

F.3.6.2.2 Impermeable Barriers. Impermeable barriers are solid walls that are placed into the subsurface to retard the movement of groundwater. Groundwater flowing toward a barrier will divert away from and eventually flow around the barrier. A barrier could be supplemented with extraction wells at the ends of the barrier to prevent mobile contaminants from migrating around the barrier.

Sheet-Pile Barrier. Sheet-pile barriers are constructed by driving interlocking sheet-piles into the ground with either vibratory or impact pile drivers. This barrier would need to be coupled with a horizontal barrier to form a complete barrier envelope. Sheet-pile barriers were tested in the 100-N Area of the Hanford Site and were unsuccessful. The piling was destroyed after penetrating to a depth of 9.2 m (30 ft). Based on the depth to groundwater, installation of a sheet-pile barrier at WMA S-SX would not be possible.

Cryogenic (Freeze-Wall) Barrier. A cryogenic or freeze-wall barrier is formed using two methods. A closed-loop system recirculates chilled brine or other refrigerants through an array of closely spaced wells or pipes, freezing and expanding the water in the soil voids surrounding the freeze pipes. An open loop system involves the injection of liquid nitrogen into the ground through perforated well casings. Cryogenic barriers may be applicable at WMA S-SX. Maintenance of a cryogenic barrier requires a long-term commitment of resources.

Chemical Jet Grout Encapsulation. Chemical jet grout encapsulation uses primarily high-pressure jet grouting to form columns of grouted soil via directionally drilled wells. Standard grouts such as portland cements or bentonite clays are used. More exotic grouts could be used for enhanced set times and better compatibility with Hanford soils. Chemical jet grout encapsulation is applicable at WMA S-SX.

Jet Grout Curtains. Jet grout curtain placement is similar to grout encapsulation described above, except that both vertical and horizontal wells, rather than directionally drilled wells, are used for injection. Jet grout curtain technology is applicable to WMA S-SX.

Permeation Chemical Grouting. Permeation chemical grouting is similar to jet grouting except that lower pressures are used for injection. Permeation chemical grouts could be injected using both vertical and horizontal wells. Permeation chemical grouting is applicable at WMA S-SX, although performance is highly dependent upon the properties of the grouting material used and the properties of the soil.

Wax Emulsion Permeation Grouting. A mineral wax-bentonite emulsion, called 'Montan' wax, has been developed for grouting applications. Montan wax grout consists of a stable emulsion of Montan wax, water, and a surfactant. Once inside the soil matrix, the wax particles begin to aggregate and move through void spaces until they bridge an opening and become fixed. Bridging the openings between pores reduces the permeability of the soil. Wax emulsion

permeation tests have been conducted at the Hanford Site and have shown that soil hydraulic conductivity can be reduced by two to three orders of magnitude.

Silica, Silicate Permeation Grouting. Sodium silicate permeation grouting uses a silicate-based chemical grout with favorable characteristics that can be controlled by altering the formulation of the grout. By altering the proportions of the components of sodium silicate grout, the set time and grout viscosity can be controlled. Colloidal silica is also being explored for use in forming subsurface barriers at the Hanford Site. Colloidal silica is a colloidal suspension with gelling properties. Tests using Hanford soils have been performed on sodium silicate grouts and colloidal silica, and have shown that soil hydraulic conductivity can be reduced by three to four orders of magnitude. This technology is potentially applicable at WMA S-SX.

Polymer Permeation Grouting. Polymer permeation grouting employs an injected liquid monomer or resin that converts to a polymer (in place) to form a concrete-like monolithic barrier. Polymer-forming chemicals could be injected into the ground using the same methods for emplacing cement slurry walls. Although some polymer grouts (e.g., furfuryl alcohol) are chemically incompatible with Hanford Site soils, polymer permeation grouting is applicable at WMA S-SX.

Formed-in-Place Horizontal Grout Barriers. Placement of formed-in-place horizontal grout barriers involves the use of a proprietary technology to generate a barrier slab of uniform thickness between guide wires placed by horizontal drilling methods. The technology uses high-pressure jets mounted on a reciprocation machine tool. The grout slurry sprayed through the jets disrupts and mixes soils to a mortar-like consistency between the guide pipes. The machine tool passes through this semi-liquid material as the hardware is pulled along the guide wires, forming a uniform barrier behind it. Adjacent panels would be placed at the edge of the previous panel (before it hardens totally), overlapping the previous panel to some extent to form an extended slab. Formed-in-place horizontal grout barriers may be applicable at WMA S-SX although the technology has never been incorporated at full scale.

Concepts Not Considered Feasible for the Hanford Site. The following concepts are not considered feasible for Hanford Site underground storage tank applications and are listed here for completeness only:

- Soil fracturing
- Longwall mining
- Modified sulfur cement
- Sequestering agents
- Reactive barriers
- Impermeable coatings
- Microtunneling
- In situ vitrification barriers
- Soil saw
- Deep soil mixing
- Slurry walls
- Soil-mixed walls.

F.3.6.2.3 In Situ Treatment Technologies. In situ treatment technologies are oriented at treating the contamination in place to either selectively extract contaminants or to stabilize and isolate contaminants from migrating in the groundwater.

Adsorption-Type Treatment Barrier. Permeable treatment beds and barriers are constructed by excavating a trench and backfilling it with a mixture of soil and adsorbents. The bed is placed downgradient of the contaminated plume. As the natural groundwater flow carries the contaminants through the bed, the contaminants that the barrier is designed to remove are adsorbed onto the bed. Adsorption-type treatment barriers would have limited applicability to WMA S-SX due to the depth of soil that would have to be excavated to reach groundwater.

Phosphate Precipitation Barrier. Phosphate compounds are used in these barriers to precipitate heavy metals (e.g., strontium-90) in the soil matrix. This technology is in the developmental stages and its applicability to WMA S-SX is not known.

Soil Flushing. Soil flushing is described in Section F.3.6.1.3. This technology is considered innovative and was considered for remediating a deep (21.4 m [70.2 ft]) aquifer (DOE-RL 1997). Use of the soil flushing technology requires mounding of the water table over a relatively large area.

Monitored Natural Attenuation. Monitored natural attenuation relies on natural processes to lower contaminant concentrations through physical, chemical, and other biological processes that, "under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants" (EPA 1999) until cleanup levels are met. Although natural attenuation methods may be readily implemented, significant action or commitment of resources (e.g., personnel to conduct sampling and perform analytical work, construction activity, and loss of land use) may be required. Monitored natural attenuation would have limited applicability at WMA S-SX for the long-lived mobile radionuclides.

F.3.6.2.4 Ex Situ Treatment Technologies. Ex situ treatment technologies are used to remove contaminants from groundwater after the groundwater has been pumped to the surface. Ex situ treatment technologies that are potentially applicable at WMA S-SX are noted below.

Precipitation Technology. Precipitation technology is used to remove metals and radionuclides from water by precipitation.

Membrane Technology. Membranes can be considered for the treatment of radionuclides (e.g., strontium-90). The membrane adsorbs the contaminant. This technology is in the developmental stage.

Ion-exchange Technology. Ion-exchange technology removes ions from solution by adsorption on a solid medium, typically an ion-exchange resin bed or column. As the groundwater is passed through the resin, ionic species in the groundwater exchange with ions on the resin and are adsorbed onto the surface of the resin.

Wet Air Oxidation. Wet air oxidation is based on a liquid-phase reaction between organics in the wastewater and compressed air. This process is used for the treatment of organics and may have limited applicability at WMA S-SX.

Activated Carbon. When contaminated wastewater is passed over activated carbon beds, organic hydrocarbon contaminants are absorbed onto the carbon. This process is used for the treatment of organics and may have limited applicability at WMA S-SX.

Tritium Treatment Technologies. The most successful treatment systems for tritium treatment and separation are gaseous phase applications as used in commercial nuclear power operations. Technologies being considered or being used for tritium are a combination of electrolysis and catalytic exchange, bithermal catalytic exchange, and membrane separation.

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APPENDIX G

REGULATORY ANALYSIS

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LIST OF TERMS

ILCR	incremental lifetime cancer risk
RCRA	*Resource Conservation and Recovery Act of 1976*
WMA	waste management area

G.1.0 INTRODUCTION

Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas (DOE-RL 2000) provides the regulatory framework for the *Resource Conservation and Recovery Act of 1976* (RCRA) Corrective Action Program. This regulatory framework is based on federal statutes and regulations, Washington State statutes and regulations, the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989); and the Hanford Site RCRA Permit (Ecology 2001). Applicable or relevant and appropriate requirements are provided in Appendix F of DOE-RL (2000).

The purpose of a field investigation report is to summarize data from a waste management area (WMA) investigation and evaluate the data to the extent necessary to determine the need for immediate action through interim measures or accelerated interim corrective measures at the WMA. At a minimum, the data is evaluated to determine the potential risk associated with hypothetical exposure to soil and groundwater at the WMA boundary as described in Section 4.0 of DOE-RL (2000). If the potential near-term risk to human health is excessive, the U.S. Department of Energy and Washington State Department of Ecology may propose one or more interim measures to mitigate the risk or may initiate an accelerated corrective measure study to evaluate and compare more complex interim corrective measures.

The evaluation of the risks associated with existing contamination serves several purposes. Some of these purposes include the following:

- Establish the need for additional interim measures or interim corrective measures
- Provide necessary input to Hanford Site-wide cumulative risk assessments
- Serve as a basis to begin identifying cleanup standards for closure.

Cleanup standards are based on both regulatory requirements and the potential risk to human health and the environment. The potential risk depends in part on the hypothetical exposure scenario, which in turn depends on the assumed land use (including surface water and groundwater). Exposure and land use scenarios are also important in identifying the appropriate regulatory requirements for cleanup. For example, the determination of cleanup standards under the "The Model Toxics Control Act Cleanup Regulation" (WAC 173-340) depends on whether an unrestricted (residential) or industrial scenario is applied, and the use of alternate concentration limits under "Concentration Limits" (WAC 173-303-645(5)) depends in part on future groundwater uses. In 1999, the U.S. Department of Energy issued *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999), which used the *National Environmental Policy Act of 1969* process to evaluate several land uses for the Hanford Site planned over the next 50 years. That environmental impact statement and associated record of decision "Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS), Hanford Site, Richland, Washington; Record of Decision (ROD)" (64 FR 61615), identify 'industrial-exclusive use' as the planned use for the 200 Areas Central Plateau, an area that encompasses the 200 East and 200 West Areas. The Washington State Department of Ecology is evaluating how the U.S. Department of Energy land-use planning efforts fit within the Washington State Department of Ecology cleanup framework; the agency has not agreed at this time to an industrial use scenario. Therefore, potential risk and the regulatory requirements for establishing media cleanup standards for the RCRA Corrective Action Program cannot be

finalized. Appendix E of this report presents the risk assessment and evaluation approach and results that considers several potential exposure scenarios identified in DOE-RL (2000).

G.2.0 REGULATORY PERFORMANCE MEASURES

Table G.1 identifies quantitative performance measures for various constituents, including hazardous and radiological contaminants. The level of protection established by the standards is expressed in terms of the maximum dose or contaminant concentration under various exposure scenarios. Each standard, therefore, reflects the determination by the regulatory agency of an appropriate level of protection that should be provided to protect human health. Generally, the spectrum of regulations reflected in Table G.1 demonstrates that the level of protection provided by regulatory agencies is consistent among the regulations whether they apply to dangerous contaminants (e.g., chemicals and metals) or radiological contaminants. The level of protection provided under the regulations ranges from between 1 incremental lifetime cancer risk (ILCR) in 10,000 (1.0×10^{-4}) and 1 in 1,000,000 (1.0×10^{-6}) on an annual basis.

The most important regulations related to this WMA S-SX field investigation report are those addressing cleanup of soils and groundwater and the associated risk or dose to human health through the groundwater exposure pathway. The following sections discuss compliance with the applicable regulations.

Table G.1. Regulatory Performance Measures

Regulation	Requirement	Performance Measure	Point-of-Compliance	Notes
DOE Order 5400.5	**Protection of the general public and environment.**			
Protection of the Public	All pathways for LLW except air (mrem/yr)	25	100 m downgradient for groundwater, at waste site for direct exposure	100 years of institutional control.
	All pathways including other Hanford sources per 10 CFR 20, DOE Order 5400.5 and DNFSB 94-2 (mrem/yr)	100	100 m downgradient for groundwater, at waste site for direct exposure	--
Protection of Groundwater (40 CFR 141)	Beta/proton emitters (mrem/yr)	4	100 m downgradient	100 years of institutional control. 500 years of passive control. 10,000 years for impacts analysis. Assumes water ingestion of 2 L/day. Alpha emitters: 15 pCi/L = 40 mrem/yr radon: 3 pCi/L = 20 mrem/yr
	Alpha emitters (pCi/L)	15		--
40 CFR 141 and DOE Order 5400.5	**Drinking water standards for select constituents with the potential for release to groundwater during operations, retrieval actions, or postclosure**			
MCLs and derived concentration guide for select constituents **Source: 40 CFR 141**	H-3	20,000 pCi/L	Drinking water source	1,000 yr for compliance analysis. Alpha Emitters: 15 pCi/L = 40 mrem/yr.
	C-14	2,000 pCi/L		
	I-129	1 pCi/L		
	U	0.02 mg/L (Total)		
	Tc-99	900 pCi/L		
	Cs-137	200 pCi/L		
	NO_3	45 mg/L		
	Cr	0.5 mg/L		

LLW = low-level waste.
MCL = maximum contaminant level.

G.3.0 REGULATORY COMPLIANCE FROM FIELD DATA

Regulatory compliance data for soils and groundwater collected during the field investigation activities are presented with comparison to regulatory requirements in Appendices B and C. The following sections discuss the new WAC 173-340 revision related to assessing derived soil concentrations for groundwater protection, "Deriving Soil Concentrations for Ground Water Protection" (WAC 173-340-747), and groundwater contamination present in WMA S-SX groundwater monitoring.

G.3.1 SOIL DATA

Under WAC 173-340-747 the term 'soil concentration' means the concentration in the soil that will not cause an exceedance of the groundwater cleanup level established under "Ground Water Cleanup Standards" (WAC 173-340-720). Six different methodologies can be used to determine if the criterion has been met. This WMA S-SX field investigation report uses the alternative fate and transport model (WAC 173-340-747(8)). The values used in the fate and transport modeling are based on best estimates and do not comply with the default values in WAC 173-340-747. The values used provide an estimate of groundwater impacts from the soil inventory estimate (see report main text Sections 3.3 and 4.2 and also Appendix E). Numerical simulation results are obtained on long-term transient contaminant concentrations at the water table and for compliance at the WMA boundary, 200 West fence boundary, 200 Area exclusion boundary, and the shoreline at the Columbia River. These compliance points are based on DOE-RL (2000). However, since the 200 Area and exclusion boundaries are relatively close, the 200 Area boundary is replaced by the 200 West fence boundary. For vadose zone modeling, three representative (west-east) cross-sectional models for the S and SX tank farms were considered:

- Cross-section through tanks, S-106, S-105, and S-104 (S-CC')
- Cross-section through tanks SX-109, SX-108, and SX-107 (SX-DD')
- Cross-section through tanks SX-115, SX-114, and SX-113 (SX-FF').

Table G.2 provides the case numbers and descriptions for the numerical simulations as discussed in Section 4.0 of the main text and Appendix E. Numerical results are obtained on long-term transient contaminant concentrations and at compliance boundaries for each cross-section at WMA S-SX (i.e., cross-sections S-CC', SX-DD' and SX-FF'); 200 West fence; 200 Area exclusion boundary; and the Columbia River shoreline (DOE-RL 2000).

The groundwater concentration values based on inventory show that for the three cross-sections analyzed (i.e., S-CC', SX-DD', and SX-FF'), drinking water standards (40 CFR 141) will be exceeded. Tables G.3 and G.4 list the predicted technetium-99, chromium, and nitrate levels and the associated 40 CFR 141 limits. Table G.3 lists the groundwater concentration values for three cross-sections at the WMA S-SX boundary. Table G.4 lists the groundwater concentration values for the 200 West fence, 200 Area exclusion boundary, and the Columbia River shoreline.

Table G.2. Case Descriptions for the Two-Dimensional Simulations

Case No.	Description*	Interim Barrier	Inventory Distribution	Meteoric Recharge (mm/yr)
1	Base case (no action alternative)	No	Uniform	100
2	Barrier alternative	Yes	Uniform	100
3	Water-line leak (25,000 gal)	No	Uniform	100
4	Clastic dike	No	Uniform	100
5	Nonuniform inventory	No	Nonuniform	100
6	Nonuniform inventory with barrier	Yes	Nonuniform	100
7	Displaced nonuniform barrier	No	Displaced	100
8	Density and viscosity effects	No	Uniform	100
9	Base case with 50% recharge	No	Uniform	50
10	Base case with 30% recharge	No	Uniform	30
11	Base case with 10% recharge	No	Uniform	10
12	Alternative inventory	No	Alternate	100
13	Water-line leak (200,000 gal)	No	Uniform	100

*See Appendix E, Section E.2.1 for details on each case.

Table G.3. Modeled Groundwater Concentrations (Average Weighted) at the Waste Management Area S-SX Boundary

Cases	Waste Management Area S-SX Boundary								
	S-CC*			SX-DD*			SX-FF*		
	Technetium-99 (pCi/L)	Chromium (µg/L)	Nitrate (µg/L)	Technetium-99 (pCi/L)	Chromium (µg/L)	Nitrate (µg/L)	Technetium-99 (pCi/L)	Chromium (µg/L)	Nitrate (µg/L)
Case 1	108,303	2,213	664,506	968,367	81,051	1,013,000	225,324	3,564	795,585
Case 2	72,309	406	450,727	144,430	7,558	684,500	158,646	677	537,589
Case 3	NA	NA	NA	NA	NA	1,018,000	224,774	3,585	799,512
Case 4	NA	NA	NA	963,655	80,265	NA	NA	NA	NA
Case 5	1,397,182	30,410	6,216,243	4,263,016	352,241	4,382,000	2,063,180	28,391	3,441,513
Case 6	970,724	5,189	4,435,798	680,842	37,588	3,339,000	1,570,750	6,073	2,622,367
Case 7	4,519,048	52,149	19,218,126	9,102,496	599,477	13,100,000	5,721,457	50,044	10,288,413
Case 8	109,403	2,214	670,553	989,573	82,621	1,024,000	228,151	3,570	804,224
Case 9	72,522	704	446,721	294,044	17,443	713,500	156,133	1,297	560,365
Case 10	40,989	237	256,661	87,491	5,692	432,400	96,837	464	339,596
Case 11	8,301	126	53,555	53,209	3,265	98,950	21,857	246	77,713
Case 12	105,711	2,090	470,283	459,994	34,973	513,700	245,979	3,007	403,447
Case 13	NA	NA	NA	NA	NA	952,200	192,024	3,395	747,834
Regulatory Standard	**900 pCi/L**	**50 µg/L**	**45,000 µg/L**	**900 pCi/L**	**50 µg/L**	**45,000 µg/L**	**900 pCi/L**	**50 µg/L**	**45,000 µg/L**

*Groundwater concentrations given are the breakthrough values for the cross-sections. See Appendix E.

Table G.4. Modeled Groundwater Concentrations (Average Weighted) at Specified Compliance Points

Cases	200 West Area Fence			200 Area Exclusion Boundary			Columbia River Shoreline		
	Technetium-99 (pCi/L)	Chromium (μg/L)	Nitrate (μg/L)	Technetium-99 (pCi/L)	Chromium (μg/L)	Nitrate (μg/L)	Technetium-99 (pCi/L)	Chromium (μg/L)	Nitrate (μg/L)
Case 1	4,890	449	9,490	380	34.9	737	128	11.9	249
Case 2	1,910	85.5	4,310	147	6.44	334	51.1	2.31	115
Case 3	4,890	452	9,500	379	35.1	738	129	12.0	250
Case 4	4,890	447	9,460	379	34.8	735	128	11.8	249
Case 5	5,290	523	10,200	411	40.8	796	139	13.8	269
Case 6	2,090	103	4,800	162	7.76	373	56.1	2.77	129
Case 7	6,890	778	13,100	542	60.9	1,030	178	20.2	339
Case 8	4,960	455	9,610	385	35.4	747	130	12.0	252
Case 9	2,500	154	5,320	191	11.7	409	66.7	4.14	142
Case 10	1,320	55.5	3,040	99.7	4.11	231	35.4	1.50	81.7
Case 11	308	7.27	745	22.6	0.513	54.8	8.28	0.189	20.1
Case 12	4,950	451	9,630	384	35.1	748	130	11.9	253
Case 13	4,760	455	9,420	368	35.3	730	125	12.0	248
Regulatory Standard	**900 pCi/L**	**50 μg/L**	**45,000 μg/L**	**900 pCi/L**	**50 μg/L**	**45,000 μg/L**	**900 pCi/L**	**50 μg/L**	**45,000 μg/L**

The predicted groundwater concentrations exceed the regulatory standards at the WMA and for most of the cases at the 200 West fence boundary. Exceedances of the groundwater maximum contaminant levels occur for all three modeled constituents at the WMA S-SX boundary (Table G.3). At the 200 West Area fence, nitrate and chromium for Case 11 did not exceed the groundwater maximum contaminant levels (Table G.4). At the 200 Area exclusion boundary (i.e., the rest of the Central Plateau including 200 Area North extending north to the base of Gable Butte), nitrate and technetium-99 did not exceed the groundwater maximum contaminant levels for any of the cases along with chromium except for Case 7 (Table G.4). At the Columbia River shoreline, no constituent exceeded the groundwater maximum contaminant levels for any of the cases (Table G.4).

G.3.2 GROUNDWATER DATA

Based on *Hanford Site Groundwater Monitoring for Fiscal Year 2000* (Hartman et al. 2001) groundwater monitoring well data for the RCRA groundwater wells associated with WMA S-SX indicate the following constituents have exceeded the 40 CFR 141 drinking water standards during fiscal year 2000:

- Antimony
- Carbon tetrachloride
- Gross alpha
- Gross beta
- Nitrate
- Nitrite
- Technetium-99
- Tritium
- Uranium.

Table G.5 provides the RCRA groundwater monitoring well exceedances for the various constituents and the number of exceedances that have occur for the fiscal year.

Groundwater monitoring well 299-W23-19 is located inside the SX tank farm and was constructed under the RCRA facility investigation conducted in June 1999.

Table G.5. Groundwater Monitoring Results Exceeding Maximum Contaminant Levels or Drinking Water Standards at Waste Management Area S-SX

Well Number	Antimony (µg/L)	Carbon Tetrachloride (µg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Nitrate (µg/L)	Nitrite (µg/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)
299-W22-39	NA	NA	NA	NA	NA	NA	NA	28,500 (3)	NA
299-W22-44	42.8 (1)	8.6 (5)	NA	NA	NA	NA	NA	NA	NA
299-W22-45	NA	12 (3)	NA	768 (3)	47,366.76 (2)	NA	2,080 (3)	NA	NA
299-W22-46	26.4 (1)	30 (3)	NA	1,830 (3)	45,596.04 (1)	NA	5,330 (3)	26,400 (3)	NA
299-W22-48	NA	5.6 (1)	NA	555 (2)	NA	NA	1,290 (1)	NA	NA
299-W22-49	44.3 (1)	6 (2)	NA	NA	NA	NA	NA	23,900 (3)	NA
299-W22-50	88.6 (1)	23 (5)	20.9 (1)	1,420 (4)	57,991.08 (1)	NA	4,240 (3)	31,400 (3)	NA
299-W23-1	NA	25 (1)	NA	110 (1)	NA	NA	NA	NA	NA
299-W23-13	30 (1)	11 (2)	NA	NA	NA	NA	NA	NA	NA
299-W23-14	NA	NA	NA	NA	134,574.7 (1)	NA	NA	208,000 (1)	NA
299-W23-15	NA	140 (3)	NA	NA	NA	NA	NA	NA	NA
299-W23-19	NA	30 (4)	NA	23,000 (4)	562,203.6 (6)	5,485.18 (4)	72,000[a] (6)	95,800 (4)	23.6 (1)
299-W23-4	NA	130 (3)	NA	NA	NA	NA	NA	NA	25.3 (3)
299-W23-9	31.7 (1)	NA	NA	56.6 (1)	165,562.3 (3)	NA	NA	502,000 (3)	20.5 (1)
DWS or MCL	6	5	15	50	45,000	3,300	900	20,000	20

Notes: **Bold** indicates an upgradient groundwater monitoring well. Number indicates the maximum result for that well during the monitoring period from October 1, 1999 to September 30, 2000. Parenthesis indicates the number of exceedance in the particular well. These are the results taken in March 2001.

DWS = drinking water standard (40 CFR 141).
MCL = maximum contaminant level.
NA = well did not exceed MCLs for the constituent.

G.4.0 HUMAN HEALTH RISK AND DOSE RESULTS COMPARISON TO REGULATIONS

As presented in main text Section 4.0 and in Appendix E, the peak ILCR, hazard index, and dose for the industrial worker scenario is used as the baseline for comparison purposes. The results indicate that for all compliance points at the WMA S-SX boundary the ILCR, hazard index, and dose exceed regulatory standards of 10^{-5}, 1.0, and 4 mrem/yr, respectively (Table G.6).

The ILCR exceeds the regulatory standard of 10^{-5} for all the cross-sections at the WMA S-SX boundary and Cases 1, 2, 5, 9, and 10 at the 200 West Area fence boundary. Based on current groundwater concentrations of technetium-99 in RCRA groundwater well 299-W23-19, the ILCR would be 5.1×10^{-3} for the industrial worker scenario. The regulatory standard is 1.0×10^{-5} (Table G.6).

The hazard index exceeds the regulatory standard of 1.0 for Case 1 at the WMA S-SX boundary and 200 West fence boundary compliance points. Cases 2, 9, 10, and 11 exceed the hazard index regulatory standard of 1.0 at WMA S-SX boundary (Table G.6).

Dose exceeds the regulatory standard of 4 mrem/yr for beta/photon emitters for Cases 1, 2, 9, 10, and 11 at the WMA S-SX boundary (Table G.6).

Table G.6. Comparison of Peak Incremental Lifetime Cancer Risk, Hazard Index, and Dose for the Industrial Worker Scenario

Case	WMA S-SX Boundary			200 West Fence	200 Area Exclusion Boundary	Columbia River Shoreline
	S-CC'	SX-DD'	SX-FF'			
Industrial Worker Peak Incremental Lifetime Cancer Risk						
1	1.15E-03	9.98E-03	2.34E-03	5.07E-05	3.94E-06	1.33E-06
2	7.68E-04	1.49E-03	1.65E-03	1.98E-05	1.53E-06	5.30E-07
9	7.70E-04	3.03E-03	1.62E-03	2.59E-05	1.99E-06	6.92E-07
10	4.36E-04	9.02E-04	1.01E-03	1.36E-05	1.03E-06	3.67E-07
11	8.82E-05	5.49E-04	2.27E-04	3.19E-06	2.35E-07	8.59E-08
Industrial Worker Peak Hazard Index						
1	1.16E+01	3.00E+02	1.96E+01	1.60E+00	1.24E-01	4.22E-02
2	5.35E+00	2.99E+01	9.77E+00	3.25E-01	2.45E-02	8.79E-03
9	6.29E+00	6.73E+01	1.19E+01	5.63E-01	4.29E-02	1.52E-02
10	3.08E+00	2.07E+01	6.30E+00	2.11E-01	1.57E-02	5.69E-03
11	7.67E-01	1.25E+01	1.43E+00	2.81E-02	2.04E-03	7.54E-04
Industrial Worker Peak Dose (mrem/yr)						
1	6.91E+01	5.94E+02	1.40E+02	3.02E+00	2.35E-01	7.94E-02
2	4.61E+01	8.86E+01	9.85E+01	1.18E+00	9.10E-02	3.16E-02
9	4.63E+01	1.80E+02	9.69E+01	1.54E+00	1.18E-01	4.13E-02
10	2.61E+01	5.37E+01	6.01E+01	8.14E-01	6.17E-02	2.19E-02
11	5.29E+00	3.26E+01	1.36E+01	1.90E-01	1.40E-02	5.12E-03

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Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795, 42 USC 901 et seq.

WAC 173-340, "The Model Toxics Control Act Cleanup Regulation," *Washington Administrative Code*, as amended.

WAC 173-303-645(5), "Concentration Limits," *Washington Administrative Code*, as amended.

WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection," *Washington Administrative Code*, as amended.

WAC 173-340-747(8), "Alternative Fate and Transport Models," *Washington Administrative Code*, as amended.

WAC 173-340-720, "Ground Water Cleanup Standards," *Washington Administrative Code*, as amended.

APPENDIX H

QUALITY ASSURANCE/QUALITY CONTROL REQUIREMENTS

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APPENDIX H
QUALITY ASSURANCE QUALITY CONTROL REQUIREMENTS

Quality assurance and quality control requirements for conducting the *Resource Conservation and Recovery Act of 1976* field investigations are addressed in Appendix A of the *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas* (DOE-RL 2000), which is known as the master work plan. Because the *Preliminary Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMA S-SX* (Henderson 1999) was published before the master work plan, its quality assurance project plan predates that of the master work plan but is substantially similar. The major areas covered in the master work plan are as follows:

- Project management
- Measurement/data acquisition
- Assessment/oversight
- Data validation and usability
- Data quality assessment.

The project management described in the master work plan is still valid, although the company responsible for the effort has shifted (is now CH2M HILL Hanford Group, Inc.) because of contract changes. The Office of River Protection is now the U.S. Department of Energy office responsible for the tasks.

The general requirements established in the master work plan for sampling methods, sampling handling and custody, analytical methods, and field and laboratory quality control have been followed in the activities described in this document. As noted in the main text to this document, there were few deviations from the work plans on sampling and these were due to operational concerns. Other requirements had no deviations.

CH2M HILL Hanford Group, Inc. management and tank farm staffs have routinely conducted safety assessments of the waste management area S-SX *Resource Conservation and Recovery Act of 1976* field investigation. There is, at this time, no separate formal quality assurance assessment by the Tank Farm Vadose Zone Project.

Informal reviews of data validity and usability have been held, mainly as part of the determination of second- and third-tier analyses and in the preparation of this waste management area S-SX field investigation report. Similarly, only informal data quality assessments have been performed, primarily because a systematic sampling approach was used rather than a random sampling design.

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DOE-RL, 2000, *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas*, DOE/RL-99-36, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Henderson, J. C., 1999, *Preliminary Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMA S-SX*, HNF-4380, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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APPENDIX I

PREPARERS

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I.1.0 PREPARERS

I.1.1 OFFICE OF RIVER PROTECTION

Robert M. Yasek, Physical Scientist

B.S.	Geophysics, New Mexico Institute of Mining and Technology	1984

Mr. Yasek has over 16 years of experience in leadership and management of government projects, both military and civilian. He currently serves as the DOE project manager for the Hanford Tank Farms Vadose Zone Project. Prior to working at Hanford, he was the DOE Lead for Thermal Testing for the DOE's Yucca Mountain Project (YMP). Additional duties at YMP included project management of borehole geophysics for the high-level waste repository program. Mr. Yasek's military experience includes project management for flight testing of advanced weapons systems for the U.S. Air Force and operations of radar and command, control and communications (C^3) systems. Between military and civilian government service, Mr. Yasek worked as a field geophysicist for a privately-owned company, specializing in borehole geophysics.

I.1.2 CORE TEAM

Frank J. Anderson, Scientist, CH2M HILL Hanford Group, Inc.

B.S.	Geological Engineering, Colorado School of Mines	1964
M.S.	Geological Engineering, University of Arizona	1968

Mr. Anderson has over 31 years of experience as a geological engineer, environmental consultant, government manager and professor involving environmental characterization, compliance and remediation, mining, geology, water resources development, and program and project management. He has worked as a consultant at five DOE sites during the past decade: Hanford and Oak Ridge reservations, Portsmouth and Paducah Gaseous Diffusion Plants, and INEEL. He has also been a manager for the U.S. Geological Survey and the U.S. Office of surface Mining, and an assistant professor of geology. Mr. Anderson was responsible for FY 2001 Interim Measures engineering design and construction activities for the Tank Farm Vadose Zone Project, and prepared Section 3.5 and Appendix F in this document.

Dwayne Crumpler, Senior Hydrogeologist, Jacobs Engineering Group, Inc.

B.S.	Geology, Lamar University	1985
M.S.	Geology, Baylor University	1989

Mr. Crumpler has over 15 years of experience in groundwater field investigations related to RCRA facility investigations and CERCLA remedial investigations at municipal landfills, Department of Defense and Department of Energy facilities. He serves as a Senior Geologist and Regulatory Specialist for the preparation of various RCRA and NEPA documents related to Hanford. He has conducted and analyzed seismic field studies, aquifer pumping tests and slug

tests, installed monitoring wells and soil borings, and conducted groundwater and surface-water sampling programs at DOE and DOD facilities. He has prepared the site-specific work plans associated with the Single-Shell Tanks RCRA corrective action program and has been involved in the single-shell tank retrieval program. He was the coordinator for the document and preparation of the human health risk analyses, regulatory analyses, introduction, approach, conclusions and recommendations for this document.

Thomas E. Jones

Tom Jones holds a Ph.D. in Inorganic/Analytical Chemistry from Washington State University and has over 20 years experience at Hanford in the areas of tank waste characterization, development of tank waste inventory estimates, and tank farm vadose zone investigations. Over the past four years, Dr. Jones has led the task developing tank leak inventory estimates.

Raziuddin Khaleel, Consulting Engineer, Environmental and Nuclear Initiatives, Flour Federal Services.

B.S.	Civil Engineering, Bangladesh University of Engineering and Technology	1966
M.S.	Water Science and Engineering, Asian University of Technology	1970
Ph.D.	Soil and Water Engineering, Texas A&M University	1977

Dr. Khaleel has over 30 years of experience in groundwater hydrology and numerical simulations of subsurface flow and transport. He was a key contributor to the Hanford Site solid waste PAs and the immobilized low-activity waste PA, particularly in the area of conceptual model development, direction of modeling, and in writing the document. For this document, he was responsible for creating the modeling data package, coordinating the modeling work, and writing of several sections.

Anthony J. Knepp, Manager, CH2M HILL Hanford Group, Inc.

B.S.	Engineering, Johns Hopkins University	1971
M.S.	Environmental Systems Engineering, Clemson University	1973

Anthony Knepp was responsible for the management and direction of the report including its conclusions and recommendations. Mr. Knepp has over 25 years of experience in environmental cleanup and has worked as a consulting engineer, project engineer, government manager, and project manager. His experience includes water resources planning, development of water supply systems, construction of industrial treatment facilities, and environmental characterization and cleanup. For the last 10 years, he has concentrated on remediation of radiologically contaminated groundwater and soils.

Frederick M. Mann, Scientist, CH2M Hill Hanford Group

B.S.	Physics, Stanford University	1970
Ph.D.	Physics, California Institute of Technology	1975

Dr. Mann is the team leader for the ILAW Performance Assessment activity, which is charged with preparing this document. He was the main author of the 1998 and 2001 versions of the Hanford *Immobilized Low-Activity Tank Waste Performance Assessment*. He has worked for over 25 years in the field of nuclear data and the application of those data to large energy facilities. He has advised the DOE and the International Atomic Energy Agency. He was the chief internal reviewer of the document.

David A. Myers, Scientist, CH2M HILL Hanford Group, Inc.

David Myers earned a Master of Science in geology and hydrology from the University of Idaho. He is a registered professional geologist in Idaho and Oregon. His work has focused on water resources, as well as environmental monitoring and remediation of groundwater contamination. Since arriving at the Hanford Site in 1974, Mr. Myers has provided technical support for the Site-Wide Groundwater Monitoring Program, as well as early development of the *Resource Conservation and Recovery Act of 1976* monitoring program for the low-level waste burial grounds. He served as a senior hydrogeologist within the environmental restoration program, actively participating in the design and implementation of groundwater remediation projects. He supports the Tank Farm Vadose Zone Project as a technical coordinator, ensuring that multiple aspects of this complex problem are integrated and coordinated. For this document, he was responsible for preparing the geology sections and field investigation activities sections in Sections 2.0 and 3.0 and Appendices B and C.

Leiloni J. Page, Sr. Technical Writer/Editor, Jacobs Engineering Group Inc.

B.A.	English, University of Idaho	1992

Ms. Page has 11 years of technical writing and editing and document publication experience. Her experience includes 8 years of working directly with managers and senior technical staff from various disciplines on highly technical risk and safety analysis documents to provide document editing, rewriting, and reorganization expertise as needed to ensure clarity, consistency, and readability. Ms. Page also works directly with project teams to develop internal production schedules and coordinates and manages document production staff to carry out editing, word processing, and graphics generation. She was the technical information coordinator for this report and maintained and coordinated the document production schedule in addition to providing technical editing support.

R. Jeffrey Serne, Staff Scientist in PNNL's Applied Geology and Geochemistry Group

B.S.	Chemistry, University of Washington	1969
B.S.	Oceanography, University of Washington	1969

Mr. Serne currently is leading the PNNL applied geochemical research and characterization efforts supporting the Office of River Protection Vadose Zone project. The goal is to determine the distribution of contaminants that have leaked from SST's and their future fate. Mr. Serne is also lead geochemist for the near-field and the far-field geochemical studies for the proposed Immobilized Low-Activity Waste repository. Finally, Mr. Serne is a co-investigator/collaborator on 4 EMSP basic science projects pertaining to the Vadose Zone. He was lead author on the four borehole characterization reports found in the appendices of the FIR.

Harold A. Sydnor, Scientist, CH2M HILL Hanford Group, Inc.

B.S.	Geology, Western Kentucky University	1979
M.S.	Environmental Resource Management	1998

Mr. Sydnor is the team leader for characterization activities inside the single-shell tank farms. He has over 20 years of experience performing geologic and hydrogeologic investigations and evaluations in the private and public sectors. He was the field team leader for characterization activities associated with the work plan addenda.

Marcus I. Wood, Principal Scientist, Waste Management, Fluor Hanford, Inc.

B.S.	Geology, University of North Carolina	1973
Ph.D.	Geology, Brown University	1980

Dr. Wood currently is responsible for developing the PA analyses for the disposal of solid low-level waste at the Hanford Site. He is the coordinating author of the Hanford Site solid waste performance assessments and has been largely responsible for the integration and the interpretation of the analytical results in those documents. He has coordinated similar analyses for the Environmental Restoration Disposal Facility (ERDF), at which wastes generated in the remediation of Hanford Site waste sites regulated under the *Comprehensive Environmental Resource Conservation and Recovery Act of 1981* and the 200 West Area low-level burial grounds are disposed. He has directed numerous projects to quantify the geochemical properties of radionuclides in the Hanford Site geohydrologic environment. He also was responsible for developing a multifunctional waste package backfill material for isolating spent fuel and high-level waste. He was responsible for the conceptual model and for writing Chapters 2 and 3.

John M. Zachara, Chief Scientist VI, Pacific Northwest National Laboratory

B.S.	Chemistry and Geology, Bucknell University	1973
M.S.	Soil/Watershed Chemistry, University of Washington	1979
Ph.D.	Soil Chemistry, Washington State University	1986

Dr. Zachara is chief scientist and one of four associate scientific directors of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) at Battelle, Pacific Northwest National Laboratory. The EMSL is a state-of-science U.S. Department of Energy user facility focused on environmental molecular science. Dr. Zachara employs various molecular spectroscopies, electron and scanning probe microscopies, and modeling techniques in the study of contaminant geochemistry. He has performed research on these subjects for over 25 years and is the author of over 120 scientific publications. Dr. Zachara coordinates EMSL research focused on the Hanford vadose zone, and he functioned as chief scientist for the Science and Technology piece of the S and SX tank farms study that is summarized in Appendix D.

I.1.3 PEER REVIEW TEAM

Charles R. Cole	Pacific Northwest National Laboratory
Karl R. Fecht	Bechtel Hanford Inc.
Prem Attanayake	Bechtel Corporation
Larry Holm	CH2M Hill, Inc.

I.1.4 SUPPORT TEAM

I.1.4.1 Field Work

Dave Curry	Resonant Sonics International
Mike Gomez	Resonant Sonics International
Kevin Hartelius (Health Physic Technician)	LMHC
Lisa Hartley (Nuclear Chemical Operator)	LMHC
Mark Hasey	Resonant Sonics International
Loyd Petty (Person in Charge)	LMHC
Kent Reynolds	Waste Management Technical Services
Greg Sullivan (Nuclear Chemical Operator)	LMHC
Wesley Worth	Resonant Sonics International

I.1.4.2 Laboratory Measurements and Analysis (all PNNL)

C. C. Ainsworth	B. N. Bjornstad	C. F. Brown
D. B. Burke	R. E. Clayton	G. W. Gee
D. G. Horton	I. V. Kutnyakov	C. W. Lindenmeier
A. V. Mitroshkov	V. L. LeGore	D. C. Lanigan
G. V. Last	C. W. Lindenmeier	M. J. O'Hara
R. D. Orr	A. T. Owen	K. E. Parker
H. T. Schaef	J. N. Serne	S. C. Smith
K. B. Wagnon	B. A. Williams	T. C. Wilson

I.1.4.3 Computer Modeling and Risk Calculations

Robert Emmel	Jacobs Engineering Group Inc.
R. Douglas Evans	Jacobs Engineering Group Inc.
Mart Oostrom	PNNL
Mark D. White	PNNL
Mark D. Williams	PNNL

I.1.4.4 Science and Technology Participants

Calvin C. Ainsworth	PNNL
Bruce Arey	PNNL
David Balkwill	Florida State University
David L. Bish	LANL
Gordon E. Brown	Stanford University
Susan Carrol	LLNL
Jeffry G. Catalano	Stanford University
Chia-chen Chen	Ohio State University
Steven J. Chipera	LANL
Mark S. Conrad	LBNL
John DePaolo	LBNL
Evan Dresel	PNNL
John C. Evans	PNNL
Orville T. Farmer	PNNL
Jim Fredrickson	PNNL
Amy P. Gamerdinger	WSU
Paul L. Gassman	PNNL
Glendon W. Gee	PNNL
Yongtian He	Ohio State University
Steven M. Heald	ANL, PNNL
David Kennedy	PNNL
Jean Kimberling	PNNL
Heather Kostandarithes	PNNL
Shu-mei Li	PNNL
Peter C. Lichter	LANL
Richard M. Lindstrom	NIST
Chongxuan Liu	PNNL
James P. McKinley	PNNL
Matthew Newville	ANL
Susan McKinley	PNNL
Odeta S. Qafoku	PNNL
Karsten Preuss	LBNL
Sarah Roberts	LLNL
Todd Schaef	PNNL
Steven C. Smith	PNNL
Peg Snow	LANL
Carl Steefel	LLNL

Steven Sutton	ANL
James E. Szecsody	PNNL
Samuel J. Traina	Ohio State University
Andy L. Ward	PNNL
Jeffrey A. Warner	Stanford University
Mark D. White	PNNL
Steve B. Yabusaki	PNNL
Isao Yamakawa	Ohio State University
Cynthia J. Zeissler	NIST
Pihong Zhao	LLNL

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